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A PROPOSED NEW HANDBOOK FOR THE FEDERAL EMERGENCY MANAGEMENT AG--ETC(U)

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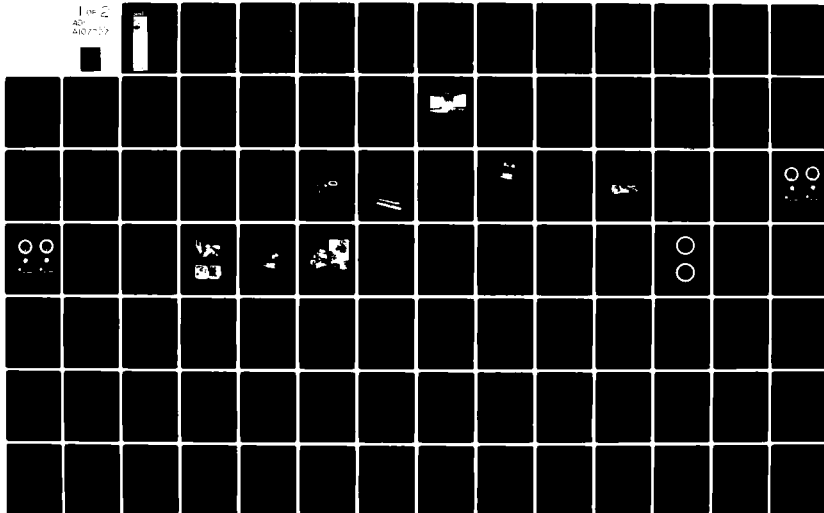
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A PROPOSED NEW HANDBOOK FOR THE FEDERAL EMERGENCY MANAGEMENT AGENCY:  
RADIATION

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**A Proposed New Handbook for the  
Federal Emergency Management  
Agency: Radiation Safety  
in Shelters**

Carsten M. Haaland

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A PROPOSED NEW HANDBOOK FOR THE FEDERAL EMERGENCY MANAGEMENT AGENCY:  
RADIATION SAFETY IN SHELTERS

by

Carsten M. Haaland

Regional and Urban Studies Section  
Energy Division

for

Federal Emergency Management Agency  
Washington, DC 20472

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This report has been reviewed in the Federal Emergency Management Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Emergency Management Agency.

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## PREFACE

This version of Radiation Safety in Shelters is published as an ORNL report to make it available for review by the community of professional people concerned with radiological defense in the United States, before being considered for final publication as a handbook. Comments, corrections, criticisms, and suggestions should be written out and mailed by April 1982 to Carsten M. Haaland, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tennessee 37830.

The term Radiological Monitor (RM) is retained to provide continuity in this long-used title, even though it will become evident after reading this handbook that the RM does more than merely monitor radiation levels in the shelter. The RM will become involved in many operations which are the responsibility of shelter management. Some of these operations are mentioned in this handbook but are not discussed in detail, because they will presumably be covered in a companion handbook for shelter management. For example, some material on ventilation was deleted from the initial draft of this handbook because it seemed to belong more appropriately in a handbook for shelter management.

## ABSTRACT

This handbook is proposed to replace the portion of the current Handbook for Radiological Monitoring that deals with protection of people in shelters from radiation from fallout resulting from nuclear war. Basic information at a high-school level is given on how to detect nuclear radiation, how to find and improve the safest places in a shelter, the necessity for and how to keep records on individual radiation exposures, and how to minimize exposures. Several new procedures are introduced, some of which are based more on theoretical considerations than on actual experiments. These procedures include: (1) the method of time-averaging radiation readings taken with one instrument in different locations of a large shelter while fallout is coming down and radiation levels are climbing too rapidly for direct comparison of readings to determine the safest location; (2) the method of using one's own body to obtain directionality in radiation readings taken with a standard Civil Defense survey meter; (3) the method of using mutual shielding to reduce the average radiation exposure to shelter occupants; and (4) the ratio method for estimating radiation levels in hazardous areas.

## ACKNOWLEDGMENTS

Many people have contributed much time toward the preparation of this handbook. The following persons have reviewed the material at various stages, and I am grateful for their helpful comments and criticisms:

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I am also indebted to Debra Swaggerty for preparing at least a dozen revisions of the handbook, a labor considerably reduced in magnitude by her proficient use of a modern word-processing system.

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## RADIATION SAFETY IN SHELTERS

a handbook for finding and providing the best  
protection in shelters with the use of instruments  
for detecting nuclear radiation

IF YOU DO NOT HAVE TIME TO READ THIS HANDBOOK AND MUST  
TAKE IMMEDIATE ACTION TO PREPARE FOR THE ARRIVAL OF RADIO-  
ACTIVE FALLOUT FROM NUCLEAR WEAPONS, TURN TO CHECKLIST "A"  
ON THE NEXT PAGE.



### CHECKLIST "A" FOR IMMEDIATE ACTION

- STEP 1. Select a Radiological Monitor (RM) for Your Shelter. If you have already been selected to be the RM, go on to STEP 2.

Read Section B of the FOREWORD, page 14. Give this copy of Radiation Safety in Shelters to the person selected to be the RM, unless he or she already has a copy and enough copies for the Radiological Monitor Assistants (RMAs) or unless you yourself are selected or were already appointed to be an RM or RMA for your shelter.

- STEP 2. Get Radiological Instruments and Forms for Radiation Exposure Records for Your Shelter. If you already have these items, go on to STEP 3. You may wish to read Sections 2b and 2c to check whether you have the right kind of instruments and forms and whether you have enough of them.

a. Where

The instruments and forms may already be in your shelter or may be on the way in the process of delivery to your shelter, or you may have to go and get them. You will have to find out what the situation is if you don't already know. Listen to your radio for information. If you don't have instruments or forms at the shelter, try to contact your local government, city or county, about getting them.

If you don't have a telephone or a two-way radio communication in your shelter or if the lines are jammed (don't spend more time trying to place your call than one-third of the time it would take you to actually get there), it may be necessary for you to get in a car and drive to your local city hall or county seat and find out about the radiological instruments. Consult your Shelter Manager about the advisability of going. Don't go if fallout has already arrived, if you expect it to arrive before you return, or if your trip will bring you closer than 15 miles to a possible target for a nuclear weapon. You can usually detect the arrival of fallout without having radiological instruments. Read the second and third paragraphs of Section 1.7, page 24.

If no radiological instruments are available, read Section 2.2, page 27.

b. What Kind

Three types of instruments are required:

- (1) survey meter (a photograph is shown in Fig. 2, page 28),
- (2) dosimeter (Fig. 3, page 29), and
- (3) charger (Fig. 4, page 31).

The survey meter and the charger each require one D cell battery, a battery commonly used in flashlights.

### CHECKLIST "A" FOR IMMEDIATE ACTION (continued)

The form for keeping records of radiation exposure is shown in Fig. 17, page 52. A few forms are at the back of the handbook. If necessary, additional forms can be Xeroxed or made by hand on any available writing surface.

#### c. How Many

- (1) Survey meters: You should have at least one survey meter if your shelter has up to 200 occupants; two survey meters (and two RMs) if your shelter has 200 to 400 occupants, and so on. You may get less because there may not be enough instruments.
- (2) Dosimeters: You should have at least one dosimeter for every 10 occupants of your shelter, plus additional dosimeters for RMs, RMAs, and shelter management. Again, you may get less because there may not be enough instruments.
- (3) Chargers: One charger can service many dosimeters. You should have about as many chargers as you have survey meters.
- (4) Batteries: You should have one extra D cell for each instrument that uses a battery.
- (5) Forms for radiation exposure records: You should have one form per shelter occupant, plus about 5% more to allow for errors, accidents, etc.

STEP 3. Check the Instruments. If you have already checked the instruments, go on to STEP 4.

If possible, get instructions and a demonstration on checking and operating the instruments from someone who knows how, perhaps from the person who delivers the instruments to your shelter or from the person who hands you the instruments at the warehouse or headquarters of your local government. If you can't get instructions, follow this procedure:

- a. Install a D cell battery in the survey meter, if it doesn't have one already. First, read Section 3.2.2, page 32, and then follow the instructions.
- b. Perform an operational check on the survey meter. First, read Section 3.2.3, page 34, and then follow the instructions.
- c. Install a D cell battery in the charger, if it doesn't have one already. First, read Section 3.3.2, page 39, and then follow the instructions.

CHECKLIST "A" FOR IMMEDIATE ACTION (continued)

- d. Perform an operational check on the charger. First, read Section 3.3.3, page 39, and then follow the instructions.
- e. Charge (zero) the dosimeters. First, read Section 3.4.2, page 44, and then follow the instructions. These instructions are the same as for the operational check of the charger, except for step 7.

STEP 4. Give Out the Dosimeters and Radiation Exposure Record Forms.

Keep one dosimeter and the extra Radiation Exposure Record forms for yourself. Each RMA (Radiological Monitor Assistant), the Shelter Manager and his assistants, and each Unit Leader should get a dosimeter. List the serial number of each dosimeter, print the name of the person to whom you issue it next to the serial number, and have the person sign his or her name to acknowledge receipt of the dosimeter. They should be instructed to wear them either in a breast pocket or clipped to the collar, neckline, or belt. Each Unit Leader should get one Radiation Exposure Record form for each person in his or her unit. Read Section 4.2.1, page 51, and Section 4.4.5, page 76, to find out what the Unit Leaders are supposed to do. At this time tell the Unit Leaders that you will tell them later what they are supposed to do with the dosimeters and forms.

STEP 5. What You Do Next Depends on the Situation. One of the following situations may apply:

- a. If fallout has already arrived at your shelter location and people are still coming to your shelter, read Section 4.4.1, page 67. If no more people are coming to your shelter, prepare to find the places with the lowest radiation levels in your shelter. Read Section 4.4.2, page 68. Read the whole section before you start to do anything.
- b. If fallout has not yet arrived at your shelter but is thought to be on the way, based on radio announcements or other signs and indicators, you should set up a watch for the arrival of fallout. Read Section 4.3, page 65. While you are waiting for fallout to arrive, you should study Section 4.4, beginning on page 67, so you will know what to do after fallout arrives. Then, if you still have time, you should study Chapter 1, which gives some facts about nuclear radiation.
- c. If a nuclear attack has not occurred but may possibly start in the next few hours, you may have time to check out the shelter and make some improvements in its radiation safety. Read Section 4.2.2, beginning on page 53. If you have time, study Chapter 1 also.

## CHECKLIST "B", STANDARD CHECKLIST FOR RADIOLOGICAL MONITORS

This checklist may be used during a crisis period when a nuclear attack is not expected for many hours or several days, if at all. It may also be used for training purposes. It is assumed that you, the RM, have studied this handbook and have been assigned to be the RM for a particular shelter in your community. If the people in your community are to be relocated in the event of a severe international crisis, you may also be assigned to be the RM for another particular shelter in the relocation area. It is also assumed that radiological instruments are at your shelter when you begin this checklist.

### STEP 1. Check the Instruments.

- a. Install a D cell battery in the survey meter, if it doesn't have one already (Section 3.2.2, page 32).
- b. Perform an operational check on the survey meter (Section 3.2.3, page 34).
- c. Install a D cell battery in the charger, if it doesn't have one already (Section 3.3.2, page 39).
- d. Perform an operational check on the charger (Section 3.3.3, page 39).
- e. Charge (zero) the dosimeters (Section 3.4.2, page 44). Record the serial number for each dosimeter and the time at which you zero it. Leave room on the list for the name of the person to whom the dosimeter will be issued.

STEP 2. Give Out the Dosimeters and Radiation Exposure Record Forms. Keep one dosimeter and extra Radiation Exposure Records forms for yourself. Issue one dosimeter to the Shelter Manager, and to each Shelter Manager Assistant, RMA, and Unit Leader. Put their names on the list by the serial numbers of the dosimeters, and have them sign the list to acknowledge receipt of the dosimeter. Issue one Radiation Exposure Record form to each of these people, except to the Unit Leader, who will need one form for each member of his or her unit.

### STEP 3. Give Instructions to Those People Given Dosimeters.

- a. Show them how to read the dosimeters. Use the illustrations on page 48.
- b. Show them how to wear the dosimeters (Section 2.4, page 29).

CHECKLIST "B", STANDARD CHECKLIST (continued)

- c. Have them copy the six radiation sensitivity categories listed in Table 3, page 53, so they will know what they are and will be able to help others fill out their forms properly.
- d. Show them how the Radiation Exposure Record will be filled out. Use the sample on page 52. The first entry will show the time at which fallout begins, in the "Comments" column. Inform the Unit Leaders that they will be responsible for estimating the radiation exposure of each individual in their units, based on the dosimeter readings on their own dosimeters, with additional exposure estimated for individuals who make special trips which subject them to greater radiation exposure.
- e. Request that they all return in 24 hours, if convenient, to the same location where the dosimeters were issued so the dosimeters can be checked for leaks (Section 3.4.3, page 46). If a dosimeter shows a reading of 2 to 3 R before the 24 hours are up and no fallout has arrived, that dosimeter should be brought back to you so you can try to get a replacement.

STEP 4. Secure the Survey Meter and Charger. Find a place where you can lock up these instruments and leave them there, or else leave them with an RMA, while they are not needed. Take the batteries out whenever you store the instruments.

STEP 5. Get a Sketch of Your Shelter Floor Plan. If your Shelter Manager doesn't have a sketch of your shelter floor plan, you should make a rough sketch or have someone among the occupants make one for you. See Figure 19, page 57, for a sample sketch of a floor plan. You may wish to walk through the entire shelter before you begin sketching. If people are gathering in the shelter and beginning to set up housekeeping, it will be helpful if you wear some type of identification, such as an armband with the initials "RM," so people will know who you are.

STEP 6. Locate the Areas Which Look Like They Will Provide the Best Protection Against Fallout (Section 4.2.2, Item 1, page 54). Have a discussion with the shelter manager about these areas.

CHECKLIST "B", STANDARD CHECKLIST (continued)

- STEP 7. Estimate Whether There Will Be Enough Room in the Locations of Best Protection (Section 4.2.2, Item 2, page 56). Discuss this situation with the Shelter Manager.
- STEP 8. Look for Ways to Improve the Shielding of the Shelter (Section 4.2.2, Item 3, page 58). If you think that significant improvements can be made with the materials, manpower, tools, and time available, discuss your plan with the Shelter Manager. In some communities, there may be detailed plans already made for upgrading your shelter during a crisis period.
- STEP 9. Check for Openings Which Might Provide a "Leak" for Gamma Radiation, or Might Let the Wind Blow Fallout Into the Shelter (Section 4.2.2, Item 4, page 59). Remember that in an overcrowded shelter you will need much more ventilation than you would ordinarily need. You will need to discuss your plans with the Shelter Manager before he assigns a work crew to cover up any openings.
- STEP 10. Locate Materials and Tools Which Might Possibly be Used for Improvising Shielding after Fallout Arrives (Section 4.2.2, Item 5, page 59).
- STEP 11. Check the Entranceways for Possible Problems (Section 4.2.2, Item 6, page 60). If the shelter is inside a large building, there should be signs showing people where to go. You may need to set up receptionists at the entrances. If you think this is necessary, discuss the situation with the Shelter Manager and let him select people to be receptionists. You will need to tell them what to do.
- STEP 12. Locate Water, Food Supplies, and Restrooms (Section 4.2.2, Item 7, page 60). Estimate whether trips for supplies or to the restrooms will require extra monitoring for radiation exposure. Check whether there is a possibility of fallout getting into your water supply. If there is such a possibility, see if the water supply can be covered. If not, you may need a supply of potassium iodide (KI) tablets to provide blocking doses to prevent the possibility of radioiodine concentrating in the thyroids of those drinking the water (Section 1.5.5, page 21). These may be obtained at a drugstore, if not available through your local government.

CHECKLIST "B", STANDARD CHECKLIST (continued)

- STEP 13. Find Locations Where Dosimeters Could be Hung or Mounted (Section 4.2.2, Item 8, page 40). At certain times, while sleeping, for example, the Unit Leaders will need to hang or mount their dosimeters in the general vicinity of their units. It would be handy to have string, tape, and thumbtacks for this purpose.
- STEP 14. Make Sure You Have a Reliable Light Source (Section 4.2.2, Item 10, page 62).
- STEP 15. Have Extra Writing Materials on Hand for Sketches, Signs, Messages, Bulletins, etc. (Section 4.2.2, Item 11, page 62). You should also have a bound (spiral or cloth bound) notebook to keep a record of events in the shelter.

## WHAT YOU WILL FIND IN THIS HANDBOOK

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## FOREWORD

## A. WHY YOU NEED THIS HANDBOOK

1. HIGH LEVELS OF NUCLEAR RADIATION CAN MAKE YOU SICK OR KILL YOU. YOU CAN DETECT NUCLEAR RADIATION WITH THE RIGHT KIND OF INSTRUMENTS. BECAUSE YOU CANNOT SEE, HEAR, SMELL, TASTE, OR FEEL RADIATION, YOU WILL NOT BE ABLE TO TELL WITHOUT THESE INSTRUMENTS WHETHER THE LEVELS OF NUCLEAR RADIATION AROUND YOU CAN MAKE YOU SICK.
2. THIS HANDBOOK WILL GIVE YOU SOME FACTS ABOUT NUCLEAR RADIATION, SUCH AS
  - A. WHAT IT IS,
  - B. HOW IT IS PRODUCED,
  - C. HOW IT CAN MAKE YOU SICK OR KILL YOU,
  - D. WHY YOU CAN'T FEEL IT,
  - E. HOW IT IS MEASURED,
  - F. HOW MUCH IS HARMFUL,
  - G. HOW YOU CAN SHIELD YOURSELF FROM IT, AND
  - H. HOW IT WILL FADE AWAY.
3. IF YOU HAVE TO ASSUME THE RESPONSIBILITIES OF RADIOLOGICAL MONITOR FOR YOUR SHELTER WITHOUT PREVIOUS TRAINING, THIS HANDBOOK WILL TELL YOU HOW TO USE INSTRUMENTS SO YOU CAN
  - A. DETECT NUCLEAR RADIATION,
  - B. FIND THE PLACES WITH THE LOWEST NUCLEAR RADIATION LEVELS IN A SHELTER,
  - C. IMPROVE THE PROTECTION OF PLACES WITH THE LOWEST NUCLEAR RADIATION LEVELS SO THE RADIATION IS REDUCED EVEN MORE,
  - D. ADVISE WHEN (AND FOR HOW LONG) SOMEONE CAN GO OUTSIDE THE SHELTER ON SHORT EMERGENCY TRIPS, AND
  - E. ADVISE WHEN TO LEAVE FOR LONGER TRIPS AND WHEN TO LEAVE PERMANENTLY.
4. IF YOU HAVE HAD TRAINING IN RADIOLOGICAL MONITORING, THIS HANDBOOK WILL BE USEFUL AS A REFERENCE.

## B. SELECTION OF RADIOLOGICAL MONITORS

The selection of Radiological Monitors (RMs) and Radiological Monitor Assistants (RMAs) for your shelter may have been made by the county or local government. In that case you are fortunate, because these people will have had some training and have given some thought to the problems of surviving a nuclear war.

If there has been no selection of RMs for your shelter or if the selected RMs are not able to get to the shelter in time, then you will need to select RMs from the men and women who have assembled at your shelter. RMs may be selected by a group gathered together of all those who have had technical training or experience and have worked with instruments. Anyone who has studied this handbook is qualified and should volunteer to be a member of the group which selects RMs for a shelter.

The number of RMs and RMAs you should have in your shelter will depend on how many people are in your shelter and whether it has unusual radiation safety problems. If there are less than 200 people in the shelter, one RM will usually be able to do the job, with one RMA for approximately every 50 people. If there are more people in the shelter, there should be an additional RM for every multiple of 200 people. Each RM should have radiological instruments. If people must walk through a hazardous radiation area to get to food, restrooms, or water, additional RMAs may be needed.

## C. PROTECTION FROM OTHER NUCLEAR WEAPONS EFFECTS

This handbook is written for radiation safety in shelters in areas that will not be affected by the primary nuclear weapons effects of blast, fire, and initial nuclear radiation. In a nuclear war, up to 90% of the land area of the contiguous United States could be covered with radioactive fallout that would deliver hazardous nuclear radiation to an unprotected person over a period of several days before decaying to much less hazardous levels. On the other hand, about 10-15% of the land area could be affected by primary nuclear weapons effects that would pose additional hazards to the population remaining there. In those areas additional safety measures must be taken that are not described in this handbook. Nearly all the radiation safety measures and procedures described in this handbook will be useful in all shelters. The procedure of watching for fallout to arrive (Section 4.3, page 65) should not be followed in shelters that are less than 25 miles from a possible target for a nuclear weapon. At such locations the possibility of other nuclear weapons effects such as blast and thermal radiation will place the RM following this procedure under greater risk than necessary.

## RADIATION SAFETY IN SHELTERS

Carsten M. Haaland

### 1. SOME FACTS ABOUT NUCLEAR RADIATION

#### 1.1 What It Is

Nuclear radiation is made up of high-energy rays. These rays are sent out from the nuclei of atoms that are radioactive. The rays pass through air, liquids, and solids much like streams of tiny bullets, but at speeds many thousands of times faster than the fastest rifle bullet. The rays are invisible, silent, and cannot be felt. There are three kinds of dangerous radiation in fallout from nuclear weapons, called alpha, beta, and gamma radiation. Alpha and beta rays are, in a way, like streams of large, slow bullets compared with the much smaller and more penetrating bullets of gamma rays, which travel at the speed of light. Gamma rays are just like X rays, except that X rays are produced without using radioactive materials. Of the three dangerous kinds of radiation from fallout, gamma radiation poses the greatest threat to human life and is the most difficult to protect against.

#### 1.2 How Fallout Radiation Is Produced

When a nuclear weapon explodes near the ground, it makes a big pit or crater. Tons of earth in the crater are instantly changed from solids into hot gas and fine dust by the tremendous heat and pressure from the bomb explosion. This hot gas and dust together with vaporized materials form a giant fireball that rises rapidly in the air to high altitudes. It becomes the top part of the familiar mushroom cloud of a nuclear explosion (Fig. 1). Much dust and earth are sucked up with the fireball. Some of this dust and heavier particles make up the stem of the mushroom cloud. The top of the "mushroom" spreads out, cools, and forms a cloud of fine particles of earth and bomb materials. This dust cloud is carried for miles by the wind and drifts down to the earth as fallout. The dust in the stem and in the mushroom cloud becomes radioactive mostly from radioactive materials created in the nuclear explosion that become stuck to part of the dust particles. The air around the particles does not become radioactive, and neither do the surface materials on which they settle. The heavier, large particles settle closer to the explosion than small particles. Small particles can be carried up to several hundred miles by the wind. Most of the fallout with which we are concerned in this handbook will come to the ground within 24 hours. Very small particles come down very slowly and may be spread over large areas of the earth's surface, over periods of many

days, even weeks. This delayed fallout is sometimes called "worldwide" fallout, although most of the fallout comes down in the hemisphere in which it is produced (Northern or Southern).

ORNL PHOTO 4871-79



Fig. 1. The mushroom cloud of a nuclear explosion.

### 1.3 How Nuclear Radiation Harms Your Body

When nuclear radiation passes through flesh, it damages some cells and destroys others. The different kinds of radiation produce different kinds of damage.

Alpha radiation is stopped by the outer skin layers and isn't harmful unless you breathe or swallow particles which send out alpha radiation. In this case, the alpha radiation may cause serious damage to the tissues inside your lungs or digestive tract. However, it is unlikely that anyone will breathe or swallow enough fallout particles to become a casualty from alpha radiation during the emergency. The fallout particles are too large to pass through the respiratory tracts without being filtered or trapped, and it is unlikely that anyone will swallow large quantities of fallout particles except under bizarre circumstances. We do not need to be concerned here about alpha radiation from fallout.

Beta radiation is much more penetrating than alpha radiation and may cause skin burns if a lot of fresh fallout particles stay on your

skin for a few hours. It may also be a greater hazard than alpha radiation if fallout particles are accidentally eaten or breathed. If fallout particles are accidentally swallowed or breathed, some of the radioactive atoms will find their way into the bones and organs of the body, where the alpha and beta radiation may possibly cause cancer years later. Again, it is unlikely that anyone will breathe or swallow enough fallout particles to become a casualty from beta radiation during an emergency, for the same reasons as given above for alpha radiation. The hazard from beta radiation is much reduced within a few days after fallout has arrived because all radioactivity in fallout from nuclear weapons decays by natural processes.

Gamma radiation is the most dangerous of the three kinds of fallout radiation because it can penetrate the entire body and cause cell damage to all parts, to the organs, blood, and bones. If enough cells in your body are damaged by gamma radiation, you will feel sick after a while. Higher levels of exposure will cause death. Even if you are exposed to enough radiation to make you sick or possibly to kill you later on, you may not feel anything while the radiation is passing through and being absorbed in your body. The reason you don't feel anything is because the nerve cells are not directly stimulated by nuclear radiation as they are by pressure and temperature.

#### 1.4 How We Measure Quantities of Nuclear Radiation

We cannot weigh nuclear radiation or collect it in a box, just as we cannot weigh or collect sunshine in a box. We must measure these things by the effects they cause. Unlike the part of sunshine that we can see, invisible nuclear radiation produces an electrical effect called ionization in the materials it passes through. This ionization can be measured by special instruments.

The roentgen (abbreviated R) is our unit of measurement for exposure to nuclear radiation. This unit is named after Prof. Wilhelm Roentgen, who was the discoverer of X rays, in 1895. The harmful effects of nuclear radiation are related to the quantity of radiation exposure a person gets. The quantity of radiation exposure will be given in units of roentgens. We use two kinds of instruments to measure nuclear radiation. One measures the total accumulated exposure to radiation, and the other measures the rate of exposure, or how quickly a radiation exposure is accumulated.

A dosimeter is a radiation detection instrument which gives its readings directly in units of roentgens. These instruments are called dosimeters because they measure the total "dose" or accumulated amount of radiation to which they are exposed.

Another kind of instrument, the survey meter, will measure the rate of exposure, in units of roentgens per hour. These instruments are called survey meters because they can be used to look over, or survey,

an area to find out what the radiation levels are and find the spots where the nuclear radiation intensity is the highest or the lowest.

## 1.5 How Much Nuclear Radiation Is Harmful?

### 1.5.1 Natural Background Levels

Low levels of nuclear radiation are a natural part of our surroundings. Radioactive elements in our own flesh and blood give off nuclear radiation, as they do in the foods we eat, the buildings we live in, and some of the water we drink. Nuclear radiation also comes from the sky and is called cosmic radiation. Nuclear radiation is part of all of our lives and has been present since the earth was formed.

In the United States, the exposure per person to natural nuclear radiation during a whole year is seldom more than two-tenths of a roentgen. These background levels of nuclear radiation are too low to be measured by the radiological instruments provided for shelters. Levels of nuclear radiation from fallout will be thousands of times higher and will be measured in roentgens per hour (R/hr) instead of roentgens per year.

### 1.5.2 Symptoms of Radiation Injury

Although nuclear radiation from the natural background damages some cells in our bodies and destroys others, we do not notice this damage. Billions of cells in our bodies die natural deaths every hour and are replaced by normal growth and repair processes. We feel no injury or sickness from exposure to nuclear radiation at the levels which exist in our natural surroundings.

But if our bodies are exposed to gamma radiation from fallout which is many thousands of times higher than the levels of natural background nuclear radiation, there will be so many cells in our bodies damaged or destroyed that some of us may become sick, and some may even die. Some or all of the symptoms of injury may appear within the first three days after exposure. These symptoms include nausea, vomiting, diarrhea, fever, irritability, a lack of energy, and a feeling of being tired. The symptoms may disappear and then come back after a week to three weeks, sometimes with diarrhea, sore throat, loss of hair, and a tendency to bleed easily. The greater the dose, the earlier the symptoms will appear. They will also be more severe and last longer. Chances of illness from infections are greater among those who are exposed to more than about 200 R, because the high radiation exposure damages the immune system in our bodies that helps fight diseases. In small children the symptoms of radiation injury will appear at lower exposures than for adults.

Beta burns will result if a lot of fresh fallout particles (enough to make you feel grimy) stay on the skin for several hours. Early symptoms of such skin contamination will include itching and burning sensations. These may soon disappear. Darkened or raised skin areas or sores may appear within one or two weeks. After two weeks or more, there may be a temporary loss of hair (it will return in about six months). The greater the exposure, the earlier the symptoms will appear. Beta burns will not be a problem if fallout particles are brushed or washed off promptly. Within a few days after fallout has arrived, its radioactivity decays so much that beta radiation will not be a hazard under most circumstances. It may be a problem if you must lie or crawl on the ground, as may be necessary in rescue operations, and your skin is covered with dust which is not removed for many hours.

We are concerned mostly about radiation injury from gamma radiation from fallout particles on the ground, buildings, trees, and shrubs around us. This radiation is called external radiation because it comes from particles which are outside our bodies.

#### 1.5.3 Effects and Levels of Sickness From Brief Exposure

When people are exposed to gamma radiation from fallout, their entire bodies are exposed, including arms, legs, head, and trunk. This kind of exposure, called whole-body or total-body exposure, differs from medical exposures in which radiation may be concentrated on one small part of the body. A total-body brief exposure to 50-200 R of gamma radiation may result in radiation sickness, but if only a part of the body such as the hand or foot is exposed to 50-200 R of gamma radiation, as in medical treatment, there will be no radiation sickness.

The human body has ways of repairing damage done to it. Because of these repair mechanisms, a total-body radiation exposure of 600 R spread out uniformly over a period of 20 years would not cause any radiation sickness. But if this exposure were received over a brief period of a week or less, it would probably result in death.

Some people may become very sick within a few weeks after being exposed for a brief time (a week or less) to a certain amount of gamma radiation from fallout. Others may be exposed to the same dose and not feel any serious effects. If the exposure is less than 50 R, the injury from radiation should not produce symptoms in anyone. Some people irradiated in this dose range might experience loss of appetite and nausea, but this could also be the result of anxiety and fear.

Doctors have described five levels of sickness which occur after brief total-body exposure to 50 R or more of gamma radiation from fallout. These levels are described here and summarized in Table 1. Additional effects are described in the books listed in the Bibliography.



Table 1. Levels of sickness and probable condition of most people after brief whole-body exposure to gamma radiation

Exposure range (roentgens)	Response	Probable condition of majority during emergency		Probable death rate during emergency	Comments
		Medical care required	Able to work		
0-50 R	No symptoms	No	Yes	0	
50-200 R	Radiation sickness, Level I	No	Yes	Less than 5 percent	Deaths will occur in 60 or more days
200-450 R	Radiation sickness, Level II	Yes	No	Less than 50 percent	Deaths will occur within 30 to 60 days
450-600 R	Radiation sickness, Level III	Yes	No <sup>a</sup>	More than 50 percent	Deaths will occur in about one month
More than 600 R	Radiation sickness, Levels IV and V	Yes	No	100 percent	Deaths will occur in two weeks or less

<sup>a</sup>Except during illness-free latent period.

Level I, 50-200 R exposure. Less than half of the people exposed to this much radiation experience nausea and vomit within 24 hours. Afterwards some people might tire easily, but otherwise there are no further symptoms. Less than 5 percent (1 out of 20) need medical care. Any deaths that occur after radiation exposure are probably due to additional medical problems (complications) a person might have at the same time, such as infections and diseases, injuries from blast, or burns from the nuclear explosion.

Level II, 200-450 R exposure: More than half of the people exposed to 200-450 R experience nausea and vomit and are ill for a few days. This illness is followed by a period of one to three weeks when there are few if any symptoms (a latent period). At the end of this latent period more than half experience loss of hair, and a moderately severe illness develops, often characterized by sore throat. Radiation damage to the blood-forming organs results in a loss of white blood cells, increasing the chance of illness from infections. Most of the people in this group need medical care, but more than half will survive without treatment. The chances of living are better for those with smaller doses and for those who get medical care. More than half are sick the first few days, but less than half die.

Level III, 450-600 R exposure: Most of the people exposed to 450-600 R experience severe nausea and vomiting and are very ill for several days. The latent period is shortened to one or two weeks. The main episode of illness which follows is characterized by much bleeding from the mouth, throat, and skin, as well as loss of hair. Infections such as sore throat, pneumonia, and enteritis (inflammation of the small

intestine) are common. People in this group need intensive medical care and hospitalization to survive. Fewer than half will survive in spite of the best care, the chances of survival being poorest for those who received the largest exposures.

Level IV, 600 to over 1000 R exposure. This level produces an accelerated version of the illness described for Level III. All the people in this group begin to experience severe nausea and vomiting. Without medication, this condition can continue for several days or until death. Death can happen in less than two weeks, without the appearance of bleeding or loss of hair. It is unlikely, even with extensive medical care, that many can survive.

Level V, several thousand roentgens exposure. Symptoms of rapidly progressing shock come on almost as soon as the dose has been received. Death occurs in a period from a few hours to a few days. It is highly unlikely that exposures of this magnitude will be experienced in fallout shelters.

#### 1.5.4 Long-Term Effects

In addition to the early sickness described above, exposure to nuclear radiation has some effects which may not show up for months or years. In a nuclear war, our first concerns will be with survival from the early effects. If the levels of nuclear radiation are low enough so that early radiation sickness is not a serious factor, then we become concerned with avoiding long-term effects. After a period of months to years has passed following an exposure to nuclear radiation levels many times higher than background levels, some of the people (less than a few percent) may develop various kinds of cancers as a result of this exposure.

In addition to effects on those exposed directly, there may also be effects on babies exposed while in the womb and genetic effects in children whose parents (one or both) were exposed to high levels of radiation. Most pregnant women who are exposed to enough radiation to cause symptoms of early radiation sickness (over 50 R), as described above, will have a miscarriage shortly after the exposure. There may be some developmental defects in the few babies born to the heavily exposed mothers.

Additional information on long-term effects may be found in the books listed in the Bibliography.

#### 1.5.5 Contamination of Food and Water

Food and water that have been exposed to nuclear radiation but not contaminated are not harmed and are fit for human consumption. If food containers, fruits, vegetables, and grains become contaminated by the presence of radioactive fallout particles on them or mixed in with them, they need not be thrown away. If the particles can be removed by

washing, scrubbing, brushing, or peeling, the food is safe for consumption.

Water in covered containers and underground sources will be safe. Water into which fallout particles have fallen may be unsafe to drink for a while, because some fission products, such as radioactive iodine, will dissolve in the water. Radioisotopes in solution in water cannot be removed by boiling or settling. The water can be purified by special filtering or chemical processes. Filtering water through soil will remove radioactive iodine, as described in Nuclear War Survival Skills. Water in large, deep lakes and rivers may not be unsafe to drink due to fallout contamination (they could still be unsafe due to other pollutants) after several hours or days after fallout has arrived, because of dilution of the radioiodine solution into large volumes of water. The radioiodine problem will almost completely disappear in any water in a few weeks or months due to natural radioactive decay, the half-life being only eight days.

There is a special medical hazard in using water for drinking which has been contaminated by dissolved radioiodines. The radioiodines may concentrate and become stored in the thyroid gland, resulting in possible radiation damage to the thyroid, thyroid tumors, hypothyroidism, or thyroid cancer. The concentration of radioiodine in the thyroid can be blocked by taking pills or drops of potassium iodide (KI). The resulting large concentration of nonradioactive iodine in the blood reduces the absorption of radioiodine by the thyroid. For children and adults, the recommended dose is 130 mg of potassium iodide taken by mouth every day for 14 days, unless it is shown before 14 days elapse that the drinking water is not contaminated or a different source is found which is known to be uncontaminated. If the same drinking water must continue to be used without knowing whether it is contaminated, the potassium iodide dose may be reduced after 14 days to half a pill, or 65 mg, of potassium iodide, taken by mouth every day by children and adults. Children under one year of age may be given half the dose taken by adults, although the adult dose would be safe. The blocking dosages of potassium iodide must be started not later than 3 to 4 hours after beginning to drink water suspected of being contaminated, preferably before beginning to drink such water. Side effects from this dosage are expected to be very rare. Persons with known allergies to iodine should not take this medication. If no potassium iodide or similar blocking agents are available and the water cannot be filtered, the EOC (Emergency Operating Center) should be consulted by telephone or radio, if possible. If the situation is critical, no one should be denied water because of possible fallout contamination.

## 1.6 How You Can Shield Yourself from Gamma Radiation

You can protect yourself from bullets by surrounding yourself with armor plate. In a similar way (but not exactly!) you can shield yourself from gamma radiation. Anything between you and the source of gamma radiation will cut down the number of rays which reach you. The heavier

or more massive the barrier between you and the source, the more the radiation is cut down.

A wall of concrete will give better protection than a wall of earth of the same thickness because the concrete wall is heavier. Concrete has a greater density than earth. But if the concrete wall is thinner than the earth wall (but the same height and width) so that the overall weight is the same, each wall will give the same protection. It's not the thickness but the total weight of material between you and the fallout that is important.

A wall of a certain thickness will stop a bullet of a certain size and speed without any doubt. For gamma rays a wall only cuts down the chances of the gamma "bullets" getting through. A wall of concrete eight inches thick will cut down the gamma radiation from fallout by about a factor of ten. Other materials will attenuate the radiation more or less effectively, depending on whether their specific gravity or density is greater or less than that of concrete.

To give you an idea of which common materials might be useful for shielding, a list of materials is given in Table 2, showing their densities compared with concrete. Note that earth is almost as good as concrete and is usually available and inexpensive. Water and gypsum wallboard are better shielding materials than wood and newspapers. Lead is the most dense shielding material of those listed. Lead bricks and sheets are often used as shielding material where little space is available but are too expensive for general use in shelters.

Table 2. A list of materials to give you an idea how good they would be as barriers against gamma radiation from fallout

(Materials with the highest densities require less thickness to cut down the gamma penetration by a given amount.)

Material	Density relative to concrete <sup>a</sup>	Thickness required relative to concrete
Aluminum	1.2	0.8
Brick, common clay	0.7	1.4
Concrete	1.0	1.0
Earth (well-packed moist humus, dry clay)	0.7	1.4
Firebrick (used in fireplaces)	0.9	1.1
Glass	1.1	0.9
Hardwood (maple or oak)	0.3	3.3
Human Body	0.4	2.5
Lead	4.9	0.2
Magazines, slick	0.4	2.5
Newspaper (flat), books, pulp magazines	0.3	3.0
Plywood (dry)	0.2	5.0
Steel	3.4	0.3
Wallboard, gypsum	0.4	2.7
Water	0.4	2.3

<sup>a</sup>Concrete of density 2.3 g/cm<sup>3</sup> (144 lb/ft<sup>3</sup>).

When fallout particles are all around you on the ground, you will need a barrier all around you to shield yourself from gamma radiation. You will also need a barrier above you, even though the fallout particles may have already settled to earth. An overhead barrier is needed because gamma radiation is scattered by air, somewhat like auto headlights are scattered by fog. The scattered gamma radiation can reach you from above. This radiation is called "skyshine," and is not as penetrating as the radiation coming directly from fallout. Fallout may settle on roofs or hillsides above your shelters, and the direct radiation from this fallout will add to the overhead radiation from scattered gamma rays. If you are in a shelter which is below ground you will need to be concerned mostly with overhead radiation.

Gamma radiation is also scattered around corners in tunnels and corridors by the air and by the material in the walls. The intensity of gamma radiation scattered around corners is much less than that of the direct radiation.

Because of the penetrating and scattering nature of gamma radiation, the unevenness of fallout, and the different thicknesses of materials between you and the fallout at different places in your shelter, you will need to use the radiation survey meter to find places where the radiation levels are lowest in your shelter. You may improve your shelter to make the radiation still lower by using available materials to build barriers between you and the strongest sources of radiation, and this instrument will help you do it right and will tell you how well you have succeeded.

### 1.7 How Fallout Radioactivity Arrives and Decays

As fallout settles on your shelter and its surroundings, the needle on your survey meter may climb steadily for some time. On the other hand, if you are well protected or if the fallout is not heavy in your location, you may see little or no indication on the survey meter. The fallout cloud or clouds may take as little as fifteen minutes or as much as several hours to arrive and begin to deposit fallout in your area. If the fallout comes from only one relatively small nuclear weapon exploded on or near the ground less than 20 miles upwind, the fallout may start to fall on your shelter in less than an hour after the explosion. After the fallout begins, it may keep on coming down for an hour or so. If you are outside (where you should not be unless you are on your way to shelter or there is an extreme emergency) you may be able to see some very fine particles coming down. You may also notice a darkness in the sky and feel gritty particles strike on your face. After several minutes, a buildup of a thin layer of fallout dust may be noticeable on the tops of cars and on window ledges. If the fallout is visible, the radiation levels are hazardous.

If the fallout comes from many large weapons exploded on or near the ground 100-200 miles upwind, the fallout may not start to fall on

your shelter for many hours. The time it takes for the fallout clouds to arrive at your location depends on how far upwind the explosions were and on how fast the winds carry the clouds to you. After the fallout begins, it may keep on coming down for several hours. Larger particles from the explosions will fall to the ground faster than the small particles. The clouds will contain mostly very small particles or fine dust by the time they arrive at your shelter, if you are well downwind of the explosion. This dust may be too fine to feel or see, although a darkening of the sky may be noticeable. The buildup of dust on surfaces will be gradual and won't be obvious. The nuclear radiation exposures from this almost invisible fallout may be just as great as or greater than the radiation exposures from the more visible fallout from explosions which are closer.

There will be a cloud of fallout particles formed by each of the ground explosions. Some of the clouds may merge. As each cloud with its trail of fallout passes over your shelter, the needle on your radiation survey meter may climb to higher levels.

After a fallout cloud passes by and when almost all the fallout particles from that cloud have reached the ground in your area, the survey meter needle will slowly begin to fall as the radioactivity from fallout decays and fades away by natural processes. The radioactive materials produced by the nuclear bomb explosion are unstable. These materials change (or decay) into a stable condition by shooting out nuclear radiation. Some materials decay into their stable form faster than others. Those that change fast are very busy producing intense nuclear radiation in the first few moments after a nuclear explosion. Those that decay more slowly may be responsible for measurable nuclear radiation years after the explosion.

Because many of the materials in the fallout cloud decay quickly, the nuclear radiation from a given quantity, say a hypothetical spoonful of fallout particles, is most intense in the first moments after detonation and rapidly falls to lower levels. For example, at about seven hours after a nuclear explosion the radiation intensity from that spoonful of fallout particles from that explosion will fall to  $1/10$ , or 10%, of the intensity at one hour. At forty-nine hours ( $7 \times 7$ ) the radiation intensity will fall to  $1/100$  ( $1/10 \times 1/10$ ), or 1%, of the intensity at one hour. This behavior has led to a rule of thumb called the 7:10 rule. This rule is useful in some cases for getting a rough idea of what the radiation level may be at some time in the future at your location after all the fallout from a particular nuclear explosion has arrived. For example, if the needle on your survey meter stops rising five hours after a nuclear explosion was observed upwind from your shelter, the needle reading at 35 hours ( $7 \times 5$ ), or about 1-1/2 days, after the explosion would be about  $1/10$  of the five-hour reading.

If there are several nuclear ground bursts detonated upwind at different times and at different distances upwind or if there is heavy rain during or after the fallout, the 7:10 rule doesn't apply. Other rules have been developed to forecast upper limits of radiation exposure, as described in Section 4.5.1, p. 79.

Decay of the radiation intensity from radioactive fallout particles takes place in the cloud as it is carried by winds toward you. Of course the radiation intensity will also be decreasing because the cloud spreads out as it moves along, and the heavier particles will be dropping out, so the number of fallout particles per cubic inch of air will be decreasing as time goes on. Radioactive materials in the clouds from distant explosions will have more time to decay and spread out while they are on their way. Many of the materials that decay quickly will have decayed to undetectable levels before reaching you. For this reason, the radiation intensity from fallout on the ground from distant explosions will decrease more slowly when it reaches the ground than the radiation intensity from fallout from closer explosions.

If the air is humid, the nuclear explosion may start a local rain. If it is already raining or if the explosion starts a rain shower, much of the radioactive material will come quickly to the ground as "rainout." When rainout occurs soon after an explosion, the fallout cloud has not had a chance to spread out as it does when carried a long way by the wind, and it has not had as much time to decay.

If the rainfall producing rainout is light, local radiation intensities may be much higher than when produced by dry fallout. If the rainfall is heavy, the radioactive material may be washed into gutters, ditches, and storm sewers. From there, it may flow into streams and rivers. Radioactive materials, like dirt particles, can collect in unpredictable locations under these circumstances. Your radiation survey meter will be needed to help you detect and avoid remaining in such locations.

## 2. INSTRUMENTS FOR DETECTING NUCLEAR RADIATION

### 2.1 What You Need

If radioactive fallout settles on your shelter and its surroundings, people in the shelter will want to know where to go and what to do for the best protection. People in your shelter will want to know whether they are going to get sick and possibly die from radiation exposure. After the worst radiation has faded away, they will want to know the risks of going outside, how long they can stay outside, and where they can go with the least radiation exposure. To answer these questions, you will need special instruments.

The levels of radiation from fallout from nuclear weapons can be much higher than those encountered in peacetime conditions. The radiation instruments developed for use by operators of nuclear reactors, by radiation therapists in hospitals, or by crewmen of nuclear submarines and ships are not suitable for the needs of people caught in the radioactive fallout of a nuclear war. These commercial instruments for peacetime purposes do not have the higher ranges which may be needed for wartime use.

To meet the special needs of people who may face radiation hazards from radioactive fallout which may result if this country is attacked by nuclear weapons, the U.S. Government has developed two kinds of radiological instruments. The survey meter is designed to help you find the places of lowest radiation intensity and to indicate where you should not go because of high radiation levels. The dosimeter is designed to help you estimate the total amount of radiation to which your body has been exposed. Without a dosimeter it would be difficult to estimate your exposure if you need to move around in places where there are different radiation intensities or if the radiation intensity rises and falls irregularly due to fallout from passing fallout clouds.

### 2.2 What If There Are No Instruments?

If people have assembled in your shelter in a nuclear war emergency and there are no radiation detection instruments in your shelter, try to obtain these instruments from your local government before fallout arrives (see STEP 2a of Checklist "A"). If no radiological instruments can be obtained, try to find the location in your shelter which you think will provide the best protection from nuclear radiation if fallout arrives (see Section 4.2.2, p. 53, "Checking out the Shelter"). Listen to your local radio station, particularly one which is tied in with the Emergency Broadcasting System (EBS), for news of approaching fallout.

If you have no radiological instruments, then you will need communications with those who do. You will need information from others, from your local EOC (Emergency Operating Center), if possible, or from EBS. If you have no radiological instruments, communications may



provide your only warning of the arrival of a radiation hazard. Remember, although the particles may be seen, heard and felt under some conditions while they are coming down, the fallout radiation itself is invisible and silent and cannot be felt.

### 2.3 The Survey Meter

A survey meter is illustrated in Fig. 2. The gamma-radiation level (exposure rate) is shown by the position of the needle on the instrument dial. When the needle points to a number on the dial, that number, when multiplied by the range-selector number (described on p. 35), will tell you the level of gamma radiation from fallout in units of roentgens per hour (R/hr) at the location of the instrument.

ORNL PHOTO 5207-79

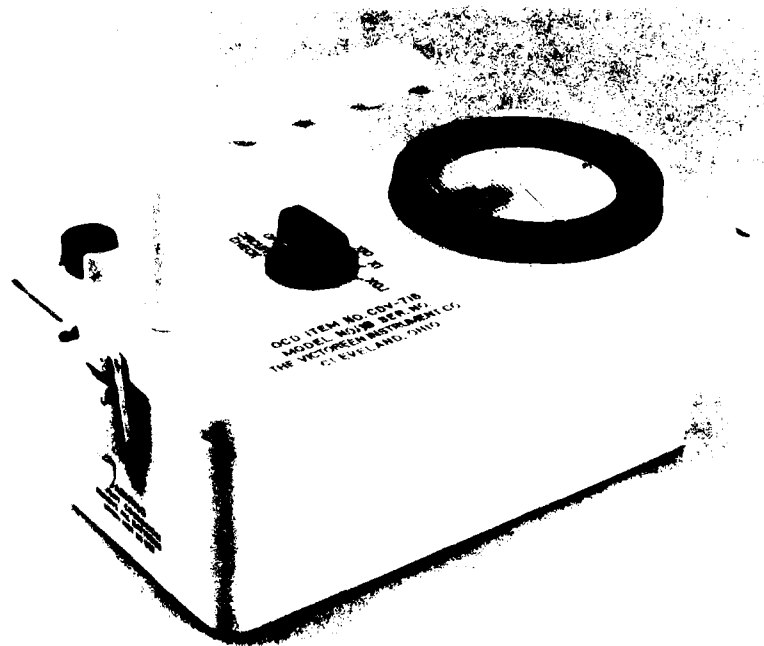


Fig. 2. A survey meter.

Gamma rays pass through the metal case of this instrument and also through the walls of a metal can, called the ionization chamber, which is inside the case. The ionization chamber is sealed to keep out moisture and dust and to keep the gas pure inside. Some of the gamma rays produce charged particles inside the ionization chamber, and these charged particles are collected to make a tiny electric current. This electric current is amplified by electronic circuits in the survey meter to make a much stronger current, which moves the needle. If the survey

meter is moved to a location where there is negligible gamma radiation, the needle will return to the zero position.

Radiation levels from fallout in a nuclear war can be very high. The highest reading on the survey meter is 500 R/hr. Because of the large range of radiation levels which you might encounter, from low to very high, this instrument was designed with a range selector switch. If this instrument had no range-selector switch, a low but still hazardous radiation exposure rate of 5 R/hr would cause an almost undetectable needle movement. This situation would compare with trying to read the speed of a car going one mile per hour on a speedometer that reads 100 mph full scale. By switching the range selector switch to a different position, the maximum range of the needle can be changed from 500 R/hr to 5 R/hr. The radiation exposure rate of 5 R/hr would then cause the needle to swing all the way through its full range of movement to the high end of the scale. With another position of the range-selection switch, readings as low as 0.05 R/hr can be read accurately.

Instructions on how to get the survey meter ready for operation and how to use it are given in Section 3.2, p. 32.

#### 2.4 The Dosimeter

A dosimeter is shown in Fig. 3 with a ballpoint pen for comparison of size. The dosimeter has a clip so it can be attached to clothing worn on the body. It is usually worn in a breast pocket. If a person's clothing has no breast pockets, the dosimeter can be clipped to the collar, neckline, or belt. In some situations, dosimeters may be mounted on walls, posts, or furniture or hung by string.

ORNL PHOTO 5204-79

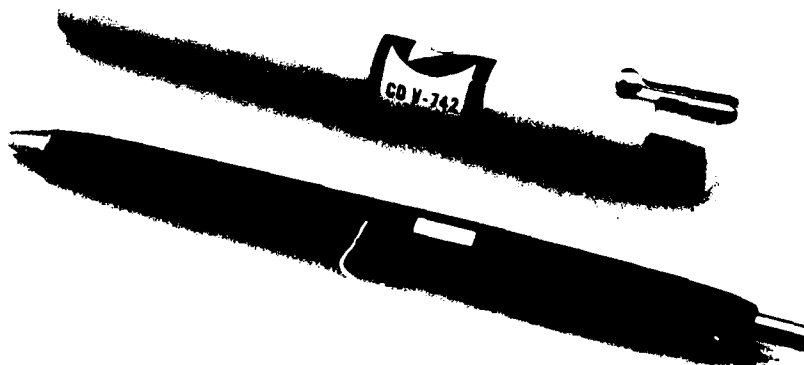


Fig. 3. A dosimeter shown with a ballpoint pen for comparison of size.

The dosimeter shows the total amount of gamma radiation to which it has been exposed starting from the time of recharging (or zeroing) the instrument. This gamma dose is read by holding the instrument so that it is pointed toward a bright light and looking through one end, the end with the clip on it. The gamma dose is shown by the position of a hairline along a scale of numbers marked "ROENTGENS." The scale has numbers which begin with zero at the left side and usually end with 200 at the right side.

The dosimeter is constructed to be reliable and rugged. The only moving part is the hairline or fiber seen through the eyepiece. Its design is based on the fact that a charge of electricity is reduced when there are charged particles around, and charged particles are produced by gamma radiation. We use a special instrument to place a charge of electricity inside the dosimeter. This charge is just like the static electricity which builds up on a person when walking along a rug on a dry winter day. The position of the fiber depends on how much static electric charge is on it. When gamma rays interact with the walls of the dosimeter and enter the chamber in which the fiber is sealed, charged particles are produced. These particles reduce the charge on the fiber, and the fiber moves to a different position. The position of the fiber as it is seen on the scale then indicates the total amount of gamma radiation to which it has been exposed from the time it was charged.

Instructions on how to get the dosimeter ready for operation and how to use it are given in Section 3.4, p. 44.

## 2.5 The Dosimeter Charger

A dosimeter charger is shown in Fig. 4. It is designed to place an electric charge on the fiber inside the dosimeter so it can be reset to zero. The charger can also be used to read the dosimeter when no light is available or when it is undesirable for various reasons to turn on a light to view the dosimeter scale.

Instructions on how to get the charger ready for operation and how to use it to reset and read the dosimeter are given in Section 3.3, p. 38.

ORNL PHOTO 5202-79

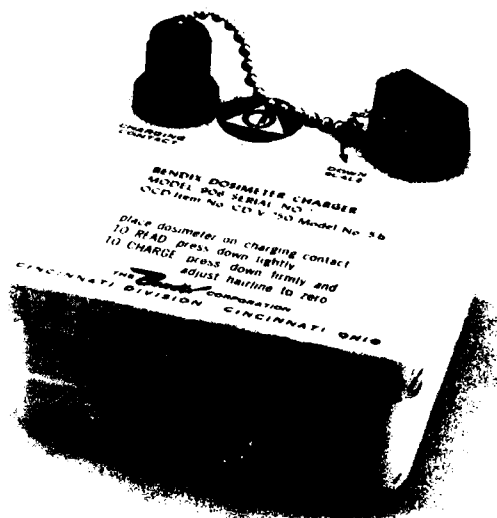


Fig. 4. Dosimeter charger.

### 3. HOW TO GET YOUR RADIOLOGICAL INSTRUMENTS READY FOR OPERATION

#### 3.1 Before You Begin

Radiological instruments could save your life, so treat them with respect! Don't drop them, don't spill liquids on them or immerse them, and don't let children play with them. If you have never used these instruments READ ALL OF THE FOLLOWING INSTRUCTIONS BEFORE YOU TRY TO OPERATE THE INSTRUMENTS.

One person should be designated to be responsible for the care and operation of each survey meter in the shelter. Other persons, or perhaps the same persons, depending on the number of people in the shelter, should be designated to be responsible for the care and use of dosimeters.

#### 3.2 Preparation for Using the Survey Meter

##### 3.2.1 Preliminary

What the survey meter measures and how it works are briefly described in Section 2.3, p. 28. The survey meter (Fig. 2) has two controls; the range-selector switch underneath the handle and the zero control on the corner. A carrying strap will be appreciated in a fallout situation when you may need to use your hands to do something else and you don't want to put down the instrument.

##### 3.2.2 Installing the Battery in the Survey Meter

The survey meter is powered by a single D cell flashlight battery. The battery is installed as follows:

1. Turn the range-selector switch (the switch underneath the handle) to the "OFF" position.
2. Open the case by unfastening the case clips at each end.
3. Use the handle to lift the top part of the survey meter out of the bottom part of the case. The top may be laid on a flat surface or held in the hand by the handle while installing the battery.

Don't let dust, sand, or moisture get in the case. If fallout particles get inside the case, you will get a false reading! Also, don't let anyone touch the circuit board or other interior parts. Grease or sweat on the electronic components may cause a malfunction.

There may be a packet inside the survey meter which may or may not be labelled "desiccant." Leave the packet inside the meter. Don't

get it wet! It will help keep the inside dry. Dryness is necessary to prevent small electric currents from leaking across insulators and to prevent corrosion.

4. Install the D cell battery in the rectangular plastic battery holder that you will see mounted on the inside of the top cover. The inside of the top cover with a battery inserted is shown in Fig. 5. One end of the floor of the battery holder will be marked with a plus sign (+) and the other end with a negative sign (-). The battery may also be marked with these signs, and if it isn't, the positive end can be identified by the raised center post. Insert the battery in the holder so the plus sign (+) on the battery or the positive electrode is on the end where the plus sign (+) is marked on the floor of the holder. Push the battery in firmly so the metal electrode clips on the ends of the holder snap over the battery ends and the battery is down in the holder as far as it will go.

ORNL PHOTO 5206-79



Fig. 5. A survey meter with the top removed. The top is shown upside down on the left. The pen points to the ionization chamber.

5. Lower the top part of the survey meter into the bottom part of the case. If there is a small rubber pad glued on one end of the inside floor of the bottom part, turn the case so the pad lines up under the battery.
6. Fasten the case clips.

### 3.2.3 Checking the Battery and the Instrument (Operational Check)

Every time a battery is inserted in the survey meter an operational check should be made to make sure the battery has been put in correctly and that it has enough energy to run the meter. An operational check should also be made each time before using the survey meter to make sure the meter is operating properly.

An operational check is made as follows:

1. Turn the range selector switch (the switch underneath the handle) to the "ZERO" position. Wait a full two minutes before doing anything else with the meter. One of the components in the survey meter is a special electronic tube (an electrometer tube), which must be warmed up before it can operate properly.
2. After waiting two minutes for warmup, rotate the knob marked "ZERO" (the knob on the corner) until the needle on the meter points to "0" (zero). If the needle doesn't move when the ZERO knob is rotated, turn the range-selector switch to "OFF" and remove the battery. Clean the battery contacts and install a new battery, unless the old one is known to be good. If the needle still doesn't move with rotation of the zero control, then the instrument is faulty and should be returned for replacement, if you have the time and opportunity.
3. After the instrument has been zeroed, turn the range-selector switch to "CIRCUIT CHECK" and hold it there against the spring pressure which will return the switch to "OFF" when the switch is released. While holding the switch in the "CIRCUIT CHECK" position, the needle should climb to the upper part of the meter scale in or near the area marked "CIRCUIT CHECK." A reading between 3 and 5 will tell you three things: (1) the battery was installed properly, (2) the battery has enough energy to run the meter, and (3) the circuits involved in this part of the test are operating properly.

If the needle does not climb up to 3 or higher while the range-selector switch is being held on "CIRCUIT CHECK," remove the battery, clean the battery contacts, and install a new battery, unless the old one is known to be good. Repeat the steps above, including the zero adjustment. If the needle still does not climb up to 3 or higher during the circuit check, the instrument is faulty and should be returned for replacement, if there is a place close enough where you may replace it and get it back before fallout arrives.

4. After the survey meter has passed the circuit check satisfactorily, rotate the range selector switch to each of the positions marked "X100," "X10," "X1," and "X0.1." Let the switch rest at each position momentarily, and observe the position of the needle on the meter. If there is no gamma radiation present besides that from normal background radiation, the needle should remain approximately at zero at each position of the switch. If it moves up scale, it should not move up more than three of the smallest divisions (not

above a 0.3 reading on the dial) when the range-selector switch points to "X100," "X10," or "X1." When the range-selector switch points to "X0.1", the needle should not move up scale from zero more than six of the smallest divisions (not above a 0.6 reading on the dial).

This small needle movement, called upscale leakage, will not affect the usefulness of the survey meter in detecting hazardous radiation levels from fallout. If the upscale leakage is greater than the limits stated above, the amount of upscale leakage usually can be reduced significantly by leaving the instrument on for 1 to 16 hours with the range-selector switch in the "ZERO" position. This procedure reconditions the electrometer tube. If excess upscale leakage still exists after 16 hours of reconditioning, then other problems exist, and the instrument should be returned for replacement, if you have the time and opportunity.

Be sure to turn the range-selector switch to the "OFF" position when the survey meter is not in use.

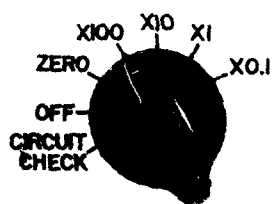
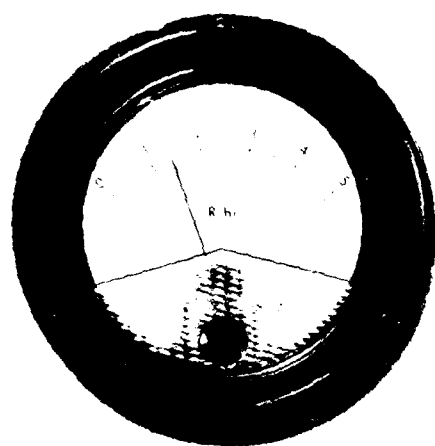
#### 3.2.4 Reading the Survey Meter

After the operational check has been made, the survey meter can be used to measure the gamma radiation exposure rate at the location of the meter, as follows:

1. Hold the meter steadily in one location at about three feet off the floor (waist height) and about two feet away from your body. The meter is to be held away from your body to reduce the effect of shielding some of the gamma radiation with your body. Turn the range-selector switch clockwise (from "X100" to "X10," then from "X10" to "X1," etc.) until you find the range position that results in the highest reading of the needle on the dial. Pause a moment or two at each range position to see how fast the needle climbs.
2. With the range-selector switch in the "X0.1" position, it will take 10-15 seconds for the needle to stop moving. It will take less time for the needle to reach a steady reading when the range selector switch is at the higher multipliers ("X1," "X10," and "X100"). There are five numbers printed on the dial, starting with "0" on the left and ending with "5" on the right. Between each printed number and the next there are ten divisions. The dial reading is obtained by taking the printed number nearest the needle on its left side, placing a decimal point to the right of that number, and then adding the number corresponding to the number of the nearest division mark to which the needle points to the right of the printed number. For example, the dial reading in Fig. 6 is 1.4. In Fig. 7 the dial reading is 0.4, and in Figs. 8 and 9, the dial readings are 4.1 and 2.5.
3. The radiation exposure rate is obtained by multiplying the dial reading by the number following the "X" at the position to which the range-selector switch points. For example, in Fig. 6 the dial reading is 1.4 and the range selector switch points to "X100," so



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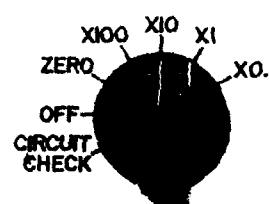
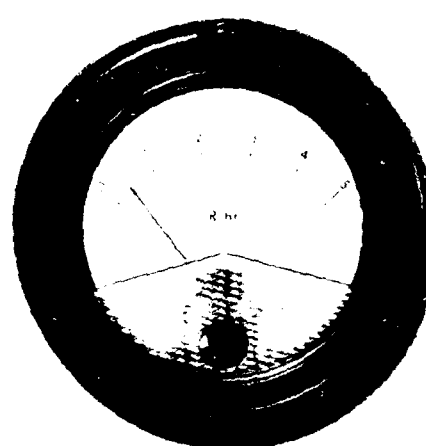


OCD ITEM NO. CDV-715  
MODEL NO. 1B SER. NO.  
THE VICTOREEN INSTRUMENT CO.  
CLEVELAND, OHIO



Fig. 6. The survey meter dial reading is 1.4. This reading is multiplied by 100 to obtain the radiation exposure rate reading because the range-selector switch points to "X100." The radiation exposure rate is 140 R/hr.

ORNL PHOTO 0718-80



OCD ITEM NO. CDV-715  
MODEL NO. 1B SER. NO.  
THE VICTOREEN INSTRUMENT CO.  
CLEVELAND, OHIO



Fig. 7. The survey meter dial reading is 0.4. This reading is multiplied by 10 to get the radiation exposure rate reading because the range-selector switch points to "X10." The radiation exposure rate is 4 R/hr.

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ORNL PHOTO 0717-80

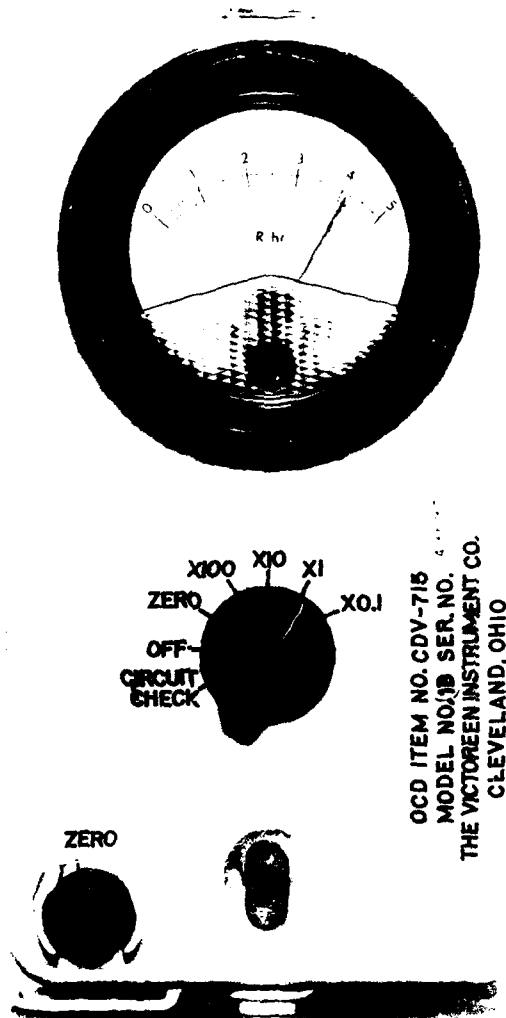


Fig. 8. The survey meter dial reading is 4.1. This reading is multiplied by 1 to get the radiation exposure rate reading because the range-selector switch points to "X1." The radiation exposure rate is 4.1 R/hr.

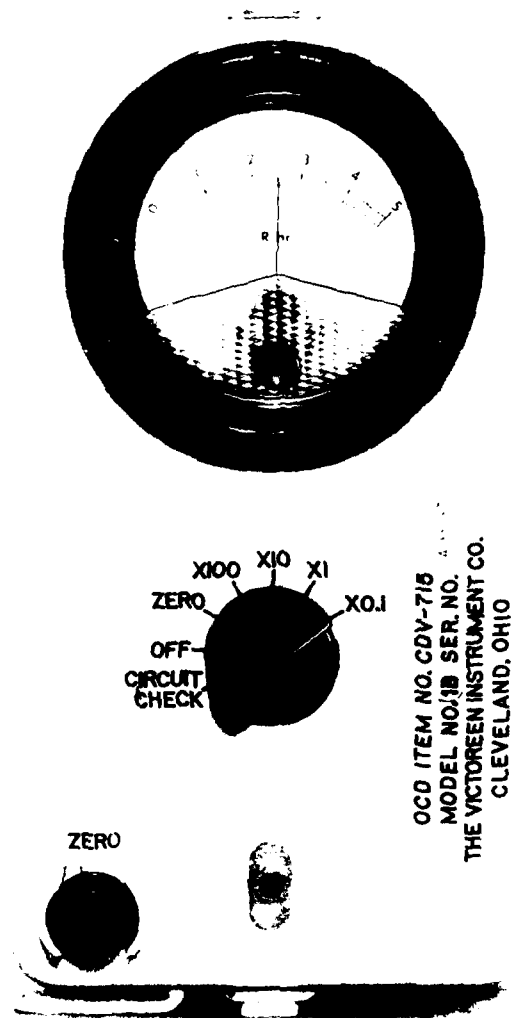


Fig. 9. The survey meter dial reading is 2.5. This reading is multiplied by 0.1 to get the radiation exposure rate reading because the range-selector switch points to "X0.1." The radiation exposure rate is 0.25 R/hr.

the radiation exposure rate is  $1.4 \times 100$ , or 140 roentgens per hour (R/hr). In Fig. 7, the dial reading is 0.4 and the range-selector switch points to "X10," so the radiation exposure rate is  $0.4 \times 10$ , or 4 R/hr. Additional examples are shown in Figs. 8 and 9.

When the dial reading is 0.5 or less, the range-selector switch should be switched one position clockwise to get a more accurate reading. In this position, where the switch points to a lower multiplier, the needle will move more for a given change in radiation rate, so you will be able to detect this change easier. For example, the range-selector switch in Fig. 7 is set at "X10" and the dial reading is only 0.4, for a radiation exposure rate of 4 R/hr. A more accurate reading of 4.1 R/hr is obtained for the same situation by switching the range-selector switch to "X1" as shown in Fig. 8, where the dial reading is 4.1.

### 3.2.5 Troubleshooting the Survey Meter

If you have trouble with the survey meter, it will probably be due to a poor battery, faulty battery installation, or poor battery contacts. Spare batteries should be kept in the shelter. With a good new battery properly installed, the survey meter should have an operating life of about 200 hours under normal operating conditions. Dirty or corroded contacts can be cleaned with a pencil eraser or steel wool or by very carefully scraping the contact surfaces with a knife. Bits of eraser, dirt, or steel wool must be very carefully and thoroughly removed from inside the case.

If radioactive dust gets on the outside of the survey meter, it should be carefully cleaned off with a cloth dampened in a mild soap solution. Instruments can be kept in a plastic bag to prevent contamination. If the inside of the meter accidentally becomes contaminated, the instrument should be taken to a clean area where the inside of the bottom case may be carefully cleaned off with a cloth dampened in a mild soap solution. It must be thoroughly dried before putting the case together. The electronic components mounted on the inside of the top cover may be brushed and dusted off with a dry brush and/or blown out with dry air. A damp cloth should not be used on any of the electronic components. If the remaining interior contamination causes a slightly increased reading only on the "X0.1" range, the instrument will still be useful.

Do not try to make any calibration adjustments or any repairs on the survey meter. Special equipment and specially trained people are necessary to do these jobs.

## 3.3 Preparation for Using the Dosimeter Charger

### 3.3.1 Preliminary

The dosimeter charger (Fig. 4, p. 31) is necessary to set the hair-line on the dosimeter back to the starting (zero) position, as described

briefly in Section 2.5, p. 30. Without a dosimeter charger, the dosimeter can't be used after the hairline has reached the end of the scale. Because the dosimeter charger is necessary to use the dosimeter, preparation of the charger is described first.

The charger has one control knob, called the voltage control. When the charger is turned so the printing on the top can be read, this knob is located on the top far-right corner of the charger. On the top left corner there is a cap with a chain coming out of the top of it; this is the charging contact. The chain keeps the cap from getting lost when the cap is unscrewed and lifted off the charging contact. The cap should be kept screwed down over the charging contact when the charger is not in use, to keep the contact clean, to prevent mechanical damage, and to prevent accidental discharge of the battery.

### 3.3.2 Installing the Battery in the Charger

The charger is powered with a single D cell flashlight battery. The battery should be removed if the charger will not be used for a few days or longer.

The battery is installed as follows:

1. Use a coin or screwdriver to unscrew the large screw at the center of the bottom\* of the charger, as shown in Fig. 10. After a few turns counterclockwise, you will feel that the bottom of the charger case is no longer attached to the top. The screw will not come out and remains attached to its part of the case.
2. Lift the bottom case up from the top.
3. Install the D cell battery in the rectangular battery holder mounted on the inside of the top cover. The insides of a charger are shown in Fig. 11, with the battery inserted in the top part shown at the left. If you have trouble deciding how the battery should be put in, read step 4 of Section 3.2.2, p. 32.
4. Notice the rubber pad glued to the inside floor of the bottom. Place the bottom part of the case over the top so the rubber pad is over the battery, and tighten the screw by turning it clockwise.

### 3.3.3 Checking the Battery and the Dosimeter Charger (Operational Check)

This procedure is also used for resetting or zeroing a dosimeter. A dosimeter is needed for a full operational check of the charger. If the dosimeter has been in use to measure radiation dose, you should write down its reading (see Section 3.4.4, p. 47) before using it to

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\*On some models the screw head is on the top.

ORNL PHOTO 5209-79



Fig. 10. A coin may be used to open the dosimeter charger to put in a battery.

ORNL PHOTO 5210-79

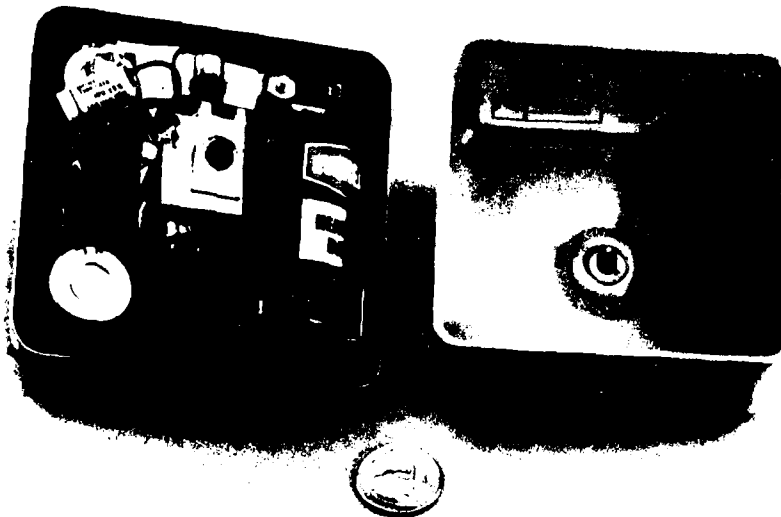


Fig. 11. The interior of a dosimeter charger with battery in place in the inside top cover. The bulb which lights to view the dosimeter is at the upper left, and an extra bulb is mounted just to the left of the battery.

check the charger. Otherwise, if the charger bulb doesn't light up, you may accidentally push the dosimeter down too far when you reach step 4 below and change the dosimeter reading. There are two levels of pressure which you will feel as you push the dosimeter down on the charging contact switch. One level, at fairly light pressure, turns on the lamp. The second level, at higher pressure, charges the dosimeter.

The operational check is made as follows:

1. Put the charger on a firm flat surface such as a table, desk top, or floor.
2. Unscrew the cap from the charging contact and lay it to one side, as shown in Fig. 12.

ORNL PHOTO 5205-79



Fig. 12. A charger with the plastic knob removed from the charging contact.

3. Place the charging end of a dosimeter, the end which is hollowed out with a center post down inside, over the charging contact, as shown in Fig. 13. You will need to use one hand to hold the dosimeter down on the charging contact and the other hand to adjust the voltage control. You may need to experiment to find out which arrangement of your hands is easiest for you to do the job. If the right hand is used on the dosimeter, you will need to rotate the charger so the printing is away from you, as shown in Figs. 13 and 14.
4. Look through the dosimeter eyepiece on the end by the pocket clip, and push the dosimeter down gently on the charging contact against the spring pressure until you can see the dosimeter scale light up.

ORNL PHOTO 5214-79



Fig. 13. Placing a dosimeter on the charger.

ORNL PHOTO 5213-79



Fig. 14. Resetting a dosimeter to zero with a dosimeter charger.

If the charger light doesn't come on, check the battery light bulb and contacts as described in Section 3.3.4 below, "Troubleshooting the Dosimeter Charger."

5. Push down the dosimeter with greater pressure on the charging contact until it reaches bottom and won't go any farther. Hold it there.
6. While the dosimeter is being held solidly down on the charging contact with one hand, use the other hand to rotate the voltage control knob. Look through the eyepiece to watch the hairline, as shown in Fig. 14. The hairline should move as you rotate the voltage control, and you should be able to make it move to the "0" (zero) at the left end of the dosimeter scale. If you can't make it move to the zero, check the next section, "Troubleshooting the Dosimeter Charger."
7. Remove the dosimeter and replace the cap over the charging contact.

#### 3.3.4 Troubleshooting the Dosimeter Charger

Always keep the protective cap on the charging contact when the charger is not in use. The smooth surface of the clear plastic insulator around the center post of the charging contact should be dry, clean, and without fingerprints. Use a soft cloth free of grit, dirt, lint, and moisture to clean it. Don't use strong solvents or cleaning fluids to clean plastic parts because some of them can dissolve plastic.

Take out the battery and keep the case closed when the charger is not to be used for periods of several days or longer.

If the light does not come on when the dosimeter is pressed down on the charging contact, do the following:

1. Check the battery and make sure that it is installed with the correct polarity (in the right direction) and that it is making good electrical contact. If the condition of the battery is questionable, replace it with a battery that is known to be good.
2. Check the light bulb to see if it is loose in the socket (see Fig. 11) and tighten if necessary.
3. Replace the bulb with the spare if there is any chance that the bulb is burned out.
4. After taking the above actions, if the light still does not come on when the charging contact is depressed, the charger should be returned for repair or replacement, if possible.

If the light is dim or appears weak, do the following:

1. Check the battery to make sure that good electrical contact is being made.



2. Clean the battery and light switch contacts with a pencil eraser or steel wool until the metal making contact is bright and shiny.
3. If the condition of the battery is questionable, replace it with a battery that is known to be good.

If the dosimeter scale is illuminated but when the voltage control knob is rotated, (1) the hairline does not appear on scale or (2) the hairline is unsteady (jittery movement of the image), do the following:

1. Check for dirt or moisture on the charging contact or on the charging end of the dosimeter, and clean it off.
2. Check for good electrical contact between the dosimeter and the outer aluminum sleeve of the charging receptacle. Press the dosimeter down firmly against the charging receptacle and rotate the dosimeter back and forth a half dozen times. Keeping the dosimeter vertical, move the dosimeter sideways to make the charging contact sleeve touch the inside wall of the dosimeter charging receptacle.
3. Check for proper electrical contact between the light switch spring contacts, and clean them if necessary (see above).
4. Try another dosimeter.
5. After taking the above actions, if the hairline image still cannot be made to appear on the scale, the charger should be returned for repair if possible.

### 3.4 Preparation for Using the Dosimeter

#### 3.4.1 Preliminary

What the dosimeter measures and how it works are briefly described in Section 2.4, p. 29. The dosimeter (Fig. 3) has no battery to install and run down and no controls to operate. As long as the hairline is on the scale when viewed through the eyepiece, the dosimeter can be considered to be turned on. It actually operates continuously. The position of the hairline on the scale can be read anytime and as often as you wish. If the hairline can't be seen, then the dosimeter is useless and must be recharged.

#### 3.4.2 Charging or Zeroing the Dosimeter

An electric charge must be placed inside the dosimeter to make the hairline visible and to reset it to the zero position on the dosimeter scale. A dosimeter charger is necessary for this operation. Exactly the same procedure is used to zero or reset the hairline of the dosimeter as is used for the operational check of the dosimeter charger.

In a fallout situation, be sure to write down the reading on the dosimeter scale, as well as the time, just before the dosimeter is charged or reset to zero. The reason for keeping such records and how to do it are described in Section 4.4.5, p. 76, "Keeping Track of Everyone's Radiation Exposure." If you use the charger to read the dosimeter, be careful not to press the dosimeter down too hard on the charging contact or else you will wipe out the reading.

The dosimeter is zeroed as follows:

1. Put the charger on a firm flat surface such as a table, desk top, or floor.
2. Unscrew the cap from the charging contact and lay it to one side, as shown in Fig. 12.
3. Place the charging end of a dosimeter, the end which is hollowed out with a center post down inside, over the charging contact, as shown in Fig. 13. You will need to use one hand to hold the dosimeter down on the charging contact and the other hand to adjust the voltage control. You may need to experiment to find out which arrangement of your hands is easiest for you to do the job. If the right hand is used on the dosimeter, you will need to rotate the charger so the printing is away from you, as shown in Figs. 13 and 14.
4. Look through the dosimeter eyepiece on the end by the pocket clip, and push the dosimeter down gently on the charging contact against the spring pressure until you can see the dosimeter scale light up. If the charger light doesn't come on, check the battery light bulb and contacts as described in Section 3.3.4, p. 43, "Troubleshooting the Dosimeter Charger."
5. Push the dosimeter with greater pressure down on the charging contact until it reaches bottom and won't go any farther. Hold it there.
6. While the dosimeter is being held solidly down on the charging contact with one hand, use the other hand to rotate the voltage control knob, and look through the eyepiece to watch the hairline, as shown in Fig. 14. The hairline should move as you rotate the voltage control, and you should be able to make it move to the "0" (zero) at the left end of the dosimeter scale. If you can't make it move to the zero, check Section 3.3.4, p. 43, "Troubleshooting the Dosimeter Charger."
7. After you have zeroed the hairline, lift the dosimeter from the charging position (which is all the way down) to the viewing position (which is almost all the way up), and check the position of the hairline. It may have drifted to one side or the other of the zero, and you will need to zero it again. After a little practice you will be able to zero the hairline quickly in one try.

8. Remove the dosimeter and replace the cap over the charging contact of the charger.

### 3.4.3 Checking Dosimeters for Leaks

Dosimeters are very reliable and rugged, but there may occasionally be one which may "leak"; that is, the hairline will slowly drift up scale to the right of zero on the scale, even though there may not be enough radiation around to make the needle move at all in a nonleaker. Most of the leakers should have been weeded out or repaired while they were in storage, but there remains a small chance that you may have a leaking dosimeter in your shelter. If you have time during a crisis period before a nuclear attack, you should check your dosimeters for leakage as follows:

1. Zero all dosimeters. Record their serial numbers and the time they are zeroed.
2. Place the dosimeters in a secure place.
3. Check each dosimeter and record the readings every 12 hours. You may wish to check them in a shorter time if you think a nuclear attack may be about to happen at any moment. You should not wait until after a nuclear attack has begun to check the dosimeters for leakage. You should record the readings and the time even though you check the dosimeters in intervals of less than 12 hours. If a nuclear attack doesn't begin, continue to check the dosimeters for four days (96 hours).
4. At the end of the leak-checking period, whether four days or less, depending on the situation, calculate the leakage per 24-hr day for each dosimeter. For this calculation use the final reading on the dosimeter at the end of the leak-checking period. Ignore the dosimeter readings taken at other times during the leak-checking period. Multiply this final reading by 24 and then divide by the total number of hours in the leak-checking period.\*

For example, if a dosimeter reads 10 R (10 roentgens) after a leak-checking period of 8 hours, the leakage rate, L, is  $L = (24 \times 10) \div 8 = 30 \text{ R/day}$ .

If a dosimeter leaks as badly as the dosimeter in this example, you can still use it, but you must calculate the leakage and subtract it from the dosimeter reading to get a correct radiation exposure reading. If there is not time or opportunity during a crisis period to exchange

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\*This calculation can be more directly specified by a formula, as follows: Let R represent the reading of the dosimeter at the end of the leak-checking period, and let T represent the total number of hours in the leak-checking period. The leakage rate per day in roentgens per day, represented by L, is calculated from the formula:  $L = 24 \text{ R/T}$  (The slash, /, means that the product, 24 R, is divided by T).

dosimeters that leak more than 2-3 R per day, they should be marked with an "L" on the body of the dosimeter, either with paint or fingernail polish, if available, or by scratching in the enamel of the dosimeter with a knife or sharp instrument. A label could be attached which shows the leakage rate. The mark or label will alert the person reading the dosimeter not to become unduly alarmed at a high reading on the dosimeter.

#### 3.4.4 Reading the Dosimeter

Reading a dosimeter has been discussed in Section 2.4, p. 29, "The Dosimeter," and in Section 3.4.2, p. 44, "Charging or Zeroing the Dosimeter." Some additional information will be given in this section.

When you point a dosimeter to a light and look through the eyepiece with your eye about 1/2 inch from the lens, you should see a field of view as illustrated in Fig. 15. You may need to rotate the dosimeter so the word "ROENTGEN" appears rightside up. The hairline is at zero in this illustration, where it should be placed whenever the dosimeter is recharged. In Fig. 16, the hairline is at about 107 R. If you read the dosimeter with the scale running up and down instead of horizontally, you will get a reading which is slightly wrong, due to the effect of gravity.

The reading of the location of the hairline on the center scale can be estimated to the nearest whole number. For various reasons you may wish to record the dosimeter reading to the nearest whole number, although the accuracy of the instrument is rated at within +20% when measuring gamma radiation from fallout. This accuracy specification means that if the actual exposure is 107 R, then the dosimeter should read between 86 R and 128 R. There are a couple of reasons for reading and recording the dosimeter to the nearest integer. In principle, your dosimeter could be calibrated at a later date, if necessary, and your recorded readings might be corrected to a more accurate value. Another reason for recording the reading to the nearest integer is that you may be interested in seeing small increases in the radiation exposure, from 18 R to 20 R, for example.

You need a light to read the dosimeter. A match, a candle, or a flashlight will do. However, the brighter the light, within reason (the sun is too bright), the easier it is to see the scale and the hairline. The dosimeter charger has a built-in light for reading the dosimeter, but the charger must be used with caution. If the dosimeter is pressed down too hard on the charging contact, the dosimeter reading will be lost.

When gamma radiation is present, the hairline of the dosimeter is moving all the time, usually so slowly that the motion can't be seen. If the radiation exposure rate is very high, the movement will become visible. For example, if the radiation exposure rate is 7200 R/hr, the hairline of the dosimeter would march across the scale at the rate of 2 R every second. This motion would be quite apparent, but it would be very unhealthy to stay and observe the motion for more than a few seconds!

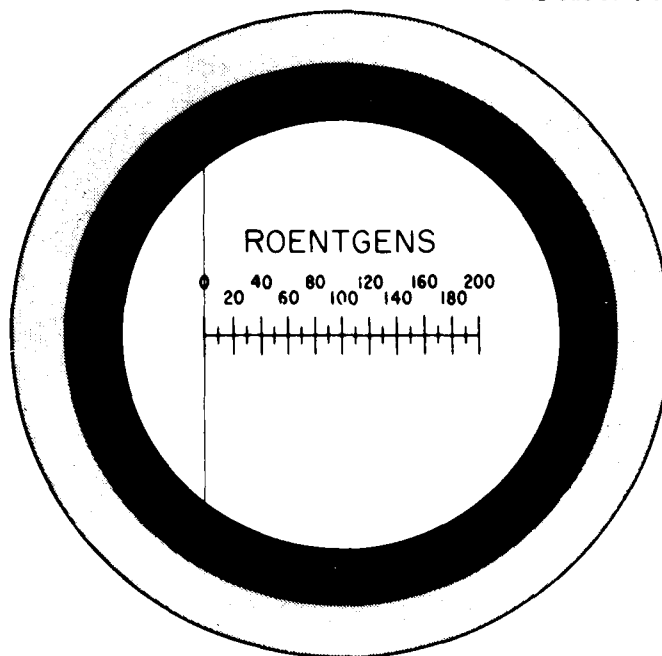


Fig. 15. Field of view of dosimeter with hairline set at zero.

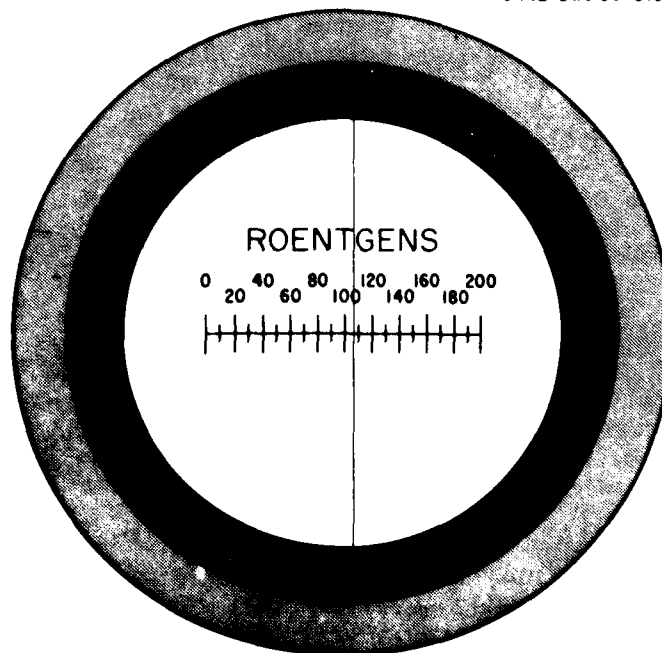


Fig. 16. Field of view seen in a dosimeter with hairline at about 107 R.

A dosimeter need not be zeroed to measure the radiation exposure for a specific period of time or a particular mission. Write down the readings taken from the dosimeter before and after the exposure. These readings are called the initial and the final readings. Subtract the initial reading from the final reading (which will always be larger) to get the exposure. For example, if the dosimeter reading is 28 R when the mission is started and 52 R when the mission is completed, the radiation exposure is obtained by subtracting 28 R from 52 R to get 24 R.

This same procedure may be used to estimate radiation exposure rates if no survey meter is available. Record the reading on the dosimeter (or reset it to zero if desired) and the time, and place the dosimeter in the location where the radiation rate is to be measured. Don't stay with the dosimeter. You won't want the exposure, and you won't want to affect the reading by shielding caused by your body. To produce a moderately accurate result, the radiation rate should be high enough to cause a change of at least 10 R in a reasonable period of time, say in 5 to 30 minutes if the measurement is being made during the first few days after fallout arrives. You may have to go to the location and read the dosimeter a few times before it shows a suitable change. When the dosimeter reading shows an increase of at least 10 R, record the new reading and the time, and remove the dosimeter from the location. Calculate the radiation exposure rate in roentgens per hour as follows:\*

1. Find the total exposure by subtracting the initial dosimeter reading from the final dosimeter reading.
2. Multiply this number (the total exposure) by 60.
3. Divide your result by the total time in minutes during which the dosimeter was exposed.

In the first few hours after fallout arrives at a location near the explosion, the radiation rate will decrease rapidly due to the decay of radioactivity. If the dosimeter is used to estimate the radiation exposure rate during this period, the actual radiation exposure rate may be significantly lower by the time the calculation is made.

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\*A formula for this calculation is defined as follows: Let D represent the total exposure in roentgens, obtained from the change in dosimeter readings, and let T represent the total time of exposure in minutes. Then the radiation exposure rate, R, in roentgens per hour is calculated from the formula:  $R = 60 D/T$ .

## 4. RADIATION SAFETY PROCEDURES

### 4.1 Introduction

The first three chapters have given you some facts about nuclear radiation, how it is detected with radiological instruments, and how to operate the civil defense radiological instruments provided for shelters. This chapter tells you how to use that information to provide the greatest possible protection from nuclear radiation while you are in shelter.

### 4.2 Before Fallout Arrives

In some localities there may be detailed planning and preparation for protection in case of a crisis or emergency during which a nuclear attack might take place. In those localities, many of the tasks described here will already be done before the crisis happens. Even in those localities where as much has been done as possible before a crisis, there will still be some tasks which should be done soon after a crisis occurs.

It may not be possible to do all these tasks before fallout arrives, and in that case, those tasks which can be done inside the shelter can be done later while fallout is arriving. Those tasks which require trips outside the shelter will have to be postponed or forgotten if they are not completed by the time fallout begins to arrive, unless special circumstances of extreme urgency or very low risk make the trips seem worth while. No one who is in a shelter when fallout begins to arrive should leave the shelter except under special circumstances of extreme urgency or very low risk.

There are two different kinds of shelter programs under development, the Community Shelter Plan (CSP) and the Crisis Relocation Plan (CRP). Either plan might be used, depending on the situation. In getting your shelter ready for possible arrival of fallout, you may do some things if one plan is used which you may not do if the other plan is used.

If a crisis develops very quickly, leading to a nuclear attack on short notice, shelters in the communities where people live would be used, that is, CSP (Community Shelter Plan) would be used. In this case there probably would not be time to do some tasks before fallout arrives, such as checking the dosimeters for leakage or improving the radiation safety of your shelter. On the other hand, you may know many of the people in the shelter and may have an idea who might be able to help with radiation monitoring and other tasks. You may also know where useful and vital supplies are located. You may also be familiar with the shelter and will not need to spend much time checking it out.

The Crisis Relocation Plan (CRP) may be used if a crisis develops gradually. There may be time in this case for people in high-risk areas, areas which might be targets, to relocate to areas of lower risk. In this case people who relocate may set up housekeeping in or near the shelter they would use if it became necessary. There would probably be time to work out an organization of the shelter population, check out the shelter, get supplies for maintaining radiation records, stockpile materials for possible use in emergency shielding, and to leak-check the dosimeters.

A discussion of things to do for radiation safety before fallout arrives is given in the next four sections. Two checklists for the RM are given at the beginning of this handbook: Checklist "A" for immediate action, and Checklist "B," a standard checklist for RMs.

#### 4.2.1 Organization of Shelter Population

The Shelter Manager and assistants will supervise the organization of the shelter population into small groups called shelter units. Organization of the shelter population into shelter units, each with its own Unit Leader, is necessary not only for good management but also to keep a radiation exposure record for each person in the shelter. There may be somewhere between 7 and 15 people in a shelter unit. There probably won't be enough dosimeters for everyone to have one. The shelter Unit Leaders can help estimate the radiation exposure of those people in their units who don't have dosimeters. The Unit Leaders can also see that someone fills out the radiation exposure record for those who are unable to do it themselves, such as small children.

Organization of the shelter population into shelter units will also be necessary in case people need to be moved to a different location in the shelter for greater radiation protection. Unit Leaders can supervise the movement to see that their units move as a group and that no one accidentally moves into a hazardous area.

After the shelter units have been organized and the Unit Leaders selected, the Unit Leaders should be instructed how to fill out the radiation exposure records. If blank forms (see Fig. 17) are available, these should be issued before fallout arrives. The Unit Leader should see that the top part of each form is filled out for everyone in the unit.

Radiation sensitivity categories are listed and described in Table 3. If a female is pregnant, she is placed in category 1, regardless of her age. Placing people in these categories before fallout arrives will be useful when it may become necessary to arrange for special shielding later on.



Home Address \_\_\_\_\_

Social Security No.

Shelter Address

Name of Shelter

Unit Leader \_\_\_\_\_

Rad. Sensitivity

Category \_\_\_\_\_

[illegible]

FRONT SIDE

[illegible]

BACK SIDE

Fig. 17. Front and back side of a form for keeping track of the individual's nuclear radiation exposure.

Table 3. Radiation sensitivity categories

Category	Description
1	Pregnant women
2	Infants, to one year old
3	Children, to 12 years
4	Youths, to 17 years
5	Adults, to 40 years
6	Adults, 40 and older

#### 4.2.2 Checking Out the Shelter

Many different kinds of shelter will be used for protection against fallout in an emergency. Some shelters may be in schools, churches, or banks. Others may be in factories, office buildings, large stores, underground garages, mines, and caves or in the basements of apartments or houses. Some shelters may have many rooms, some of them on different levels, and others may have just one large room. The problems of providing the best radiation safety will be a little different in each shelter.

The Emergency Operating Center (EOC) should be consulted if special problems arise which are not discussed in this handbook. Finding a solution for some of these problems may mean the difference between life and death for some of the people in your shelter. These solutions may depend on how good you are at inventing and putting together ideas on the spot and being able to do things in a difficult situation.

Here is a list of things to check out and do in your shelter before fallout arrives. Each item is discussed in greater detail below the list. Two checklists are given at the beginning of the book. You, in cooperation with the Shelter Manager and others, will have to work together on many of these items.

1. Which locations look like they will provide the best protection against fallout? Sketch a shelter floor plan, and mark these locations.
2. Is there going to be enough room for all the people at this shelter in the locations of best protection?
3. Can the radiation safety of the shelter be improved with tools, materials, and manpower on hand?
4. Are there openings to be baffled or covered to reduce the amount of radiation coming through them? Will these changes allow enough air

to flow through to keep people from getting too hot when they are overcrowded?

5. Are materials and tools handy which could be used for putting up additional improvised shielding inside the shelter after fallout arrives?
6. Is there going to be a problem if a lot of people enter the shelter while fallout is coming down? Are brooms and dustpans on hand to sweep up fallout particles?
7. Are trips for water or to restrooms going to increase radiation exposure?
8. Where could dosimeters be mounted or hung? Are materials needed and available for mounting or hanging them?
9. Where can instruments, instrument supplies, flashlights, batteries, etc., be stored?
10. Are there enough candles, lanterns, flashlights and other light sources to provide light so you can move around and read your instruments if the power goes out?
11. Are printed forms or paper available for keeping records of radiation exposure? Do you have a notebook in which to keep a record (RM log) of events?

Item 1: Which locations look like they will provide the best protection against fallout?

The best protection is provided by getting as much mass as possible between you and the fallout. You will need to walk through your shelter and get an idea where the best protected areas might be. Usually, but not always, the areas having the least amount of daylight reaching them will provide the best protection.

Basements provide good protection from the sides if they are well below ground and there is earth all around, but they may not always provide good protection from "skyshine" or from radiation from fallout which has settled above the basement or on neighboring rooftops.

Tall buildings can provide good protection from gamma radiation in the inner rooms of the fourth floor and up. There should be at least three stories above the shelter to provide protection from fallout on the roof. These locations do not provide blast protection and should not be used in high-risk areas.

If we expect the gamma radiation from fallout to be reduced at a certain location by a factor of 2 from what the radiation level would be outside above a very large flat, smooth open area, we say the fallout protection factor or FPF of that location is 2. This factor is also

called the protection factor, or PF. Some locations which are rated with a high protection factor, such as shelters in the upper levels of a skyscraper, may provide little protection against nuclear weapons effects such as blast. A high FPF for a shelter location only indicates good protection against gamma radiation from fallout. Such a shelter location may also, but not necessarily, provide protection against other nuclear weapons effects. We will use the term FPF in this handbook instead of PF to indicate the protection provided by a shelter location against gamma radiation from fallout.

Some FPFs that might be possible in different locations in buildings are shown in Fig. 18. Deep basements and buried shelters have high FPFs and provide very good protection against gamma radiation from fallout. The first floors of houses and partially buried basements have low FPFs and provide little protection against gamma radiation from fallout.

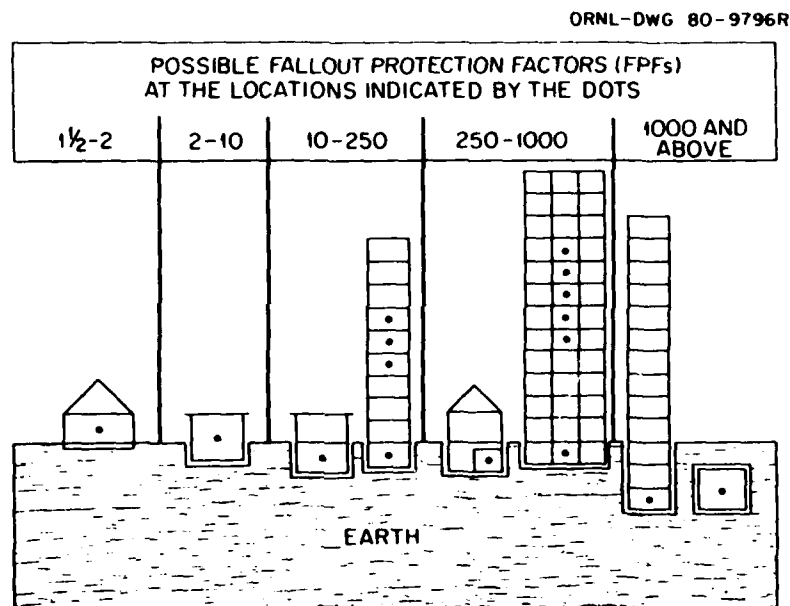


Fig. 18. Deep basements and buried shelters have high FPFs (1000 and above). They provide good protection against gamma radiation from fallout. Tall buildings also provide good protection against gamma radiation from fallout, but they provide little protection against blast.

The Shelter Manager may have a sketch of your shelter floor plan or may make arrangements to have one drawn. This sketch should show roughly how the rooms are arranged, the approximate sizes of the rooms, where windows and doors are located, and if possible, what kind of materials are used to make the walls. You will use this sketch to keep track of

your radiation measurements at different locations, where most of the people are located at different times, and where you might have to construct special shielding. You might ask someone in the shelter to draw or trace several copies for you so you will have a copy for each set of information, circumstances, or instructions.

A sample sketch of a basement of an apartment building is shown in Fig. 19. We will call this make-believe building Erskine Hall, and we will use it for several examples. The side view is included because it shows how deep the basement sits in the ground and that the ceiling is a concrete slab which provides good shielding against gamma radiation. It is not always necessary to sketch a side view, but you might want to include one to show a particular feature of your shelter.

The sketch in Fig. 19 shows the location of four drain pipes from roof gutters. If there were moderate to heavy rainfall after fallout, there could be pileups of fallout by the drainpipes which could increase the gamma radiation along the walls on the inside of the shelter opposite the drain pipes.

Two kinds of interior wall construction are indicated in the sketch in Fig. 19, concrete block and wallboard, probably gypsum. The rooms have been named with letters of the alphabet. Room "G" looks like it would provide the highest FPFs because it is surrounded by outside rooms and has walls of concrete block.

Item 2: Is there going to be enough room for all the people at this shelter in the locations of best protection?

After you have found the locations which look like they will provide the best protection, you should talk with the Shelter Manager about the problem of having enough room. To answer this question you will need to know two things: (1) how many people are in or assigned to your shelter and (2) how much space there is for people in the locations of best protection.

The Shelter Manager should be able to tell you how many people are already in your shelter or are assigned to it. He should have a list of names and radiation sensitivity categories (Table 3, p. 53) of occupants, names of shelter unit leaders, and what kinds of special skills are available.

To answer the second part of the question you will need the sketch of the floor plan with the approximate dimensions of rooms. This sketch may not show what is in the rooms. You will need to look at the rooms which you have estimated to be the safest to see if there are furniture, equipment, and obstructions which can be moved to increase the space for holding people.

Bookcases, boxes, chests, desks, and file cabinets may be moved from the rooms expected to have the highest FPFs into the rooms with

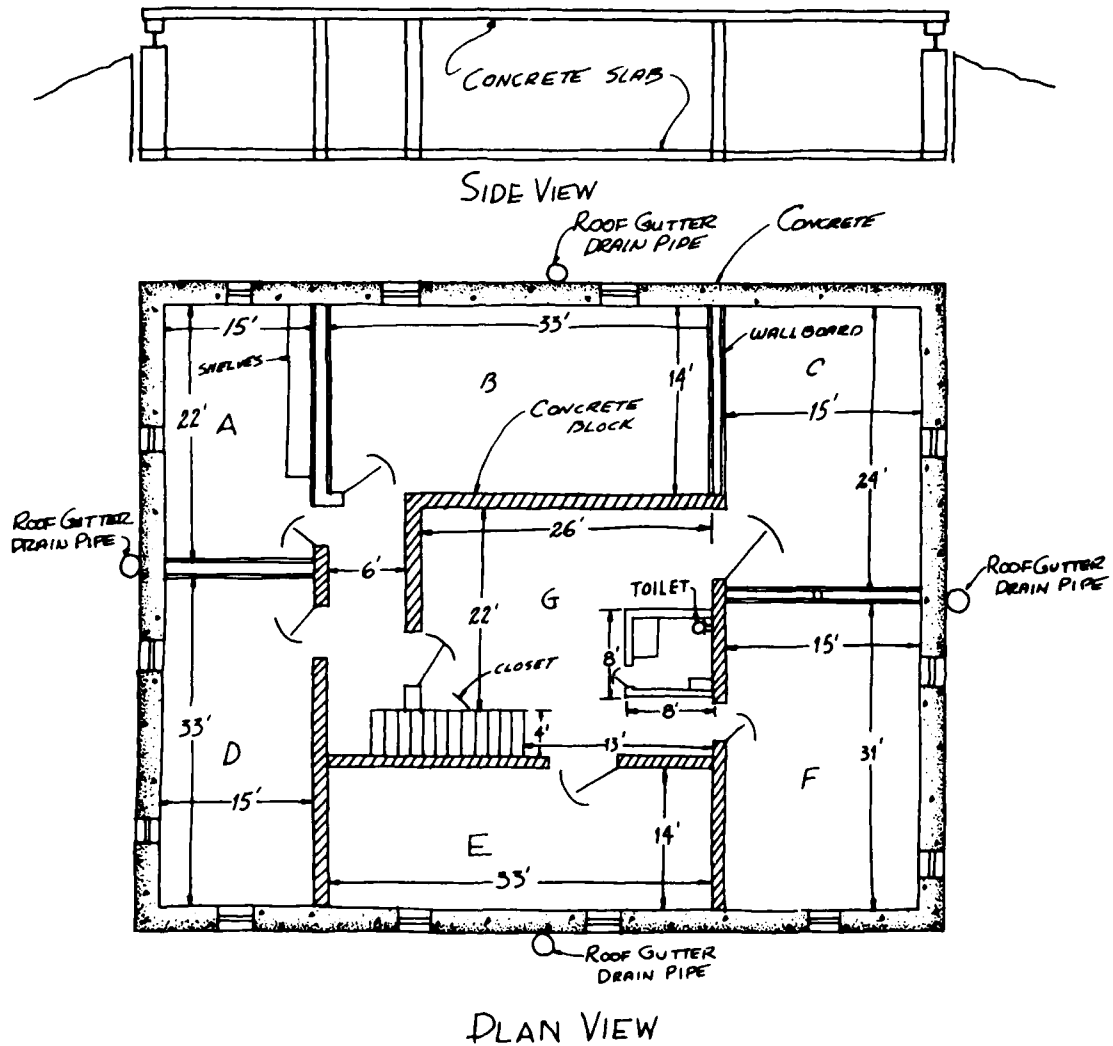


Fig. 19. Example of a sketch of the floor plan of the basement of a make-believe apartment building called Erskine Hall.

lower FPFs. Some kinds of tables should not be moved because people (especially children) may sit under them as well as on top, thus doubling the space. Storage shelves with wide sturdy shelves can also be used to hold people at more than one level.

If you aren't sure which rooms have the highest FPFs, you may hold off moving items until after fallout arrives and the radiation builds up to levels you can detect with the survey meter. Then the survey meter may be used to find the locations with the lowest radiation levels, as described in Section 4.4.2, p. 68.

During the early hours after fallout arrives, it may become necessary to crowd people in the safest locations. After the radioactivity decays to a lower level, usually after 24 hours, the occupants can spread out into rooms with lower FPFs. You can get an idea of whether you may need to crowd people by estimating the total available space in square feet of the safer locations. Divide that number by 10, the number of square feet allowed per person without crowding. If the resulting number is larger than the number of shelter occupants, you have plenty of space in the safer locations. If the number is smaller than the number of shelter occupants, you will need to crowd people temporarily in the safer locations. You can double the number of people in the safer locations if you crowd them temporarily by squeezing down the space per person from 10 sq ft to 5 sq ft.

In the sketch shown in Fig. 19, the available floor space in Room G, including the toilet, is about 624 sq ft. The hallway to the left of Room G adds about 132 sq ft for a total of 756 sq ft in the estimated safer locations. Divide 756 by 10, and round off to 76. If more than 76 people are assigned to the apartment basement in Fig. 19, they will need to be crowded in Room G and the hallway if the radiation builds up to hazardous levels after fallout arrives. With maximum crowding, they could squeeze about 152 people into Room G and the hallway during the most hazardous times. If more than 152 people were assigned to this shelter, some of them would have to be sheltered in the outer rooms, which are not as safe. In that case they might work out a rotation scheme so people would share, as fairly as possible, the higher radiation exposures of the outer rooms.

If you expect to be crowding people in the safer locations, it is very important that enough fresh air and light are provided so that people don't pass out from heat prostration or get claustrophobia (fear of confined, crowded places) and run outside. Both the Shelter Manager and the RM will be involved in these problems.

Item 3. Can the radiation safety of the shelter be improved with tools, materials, and manpower on hand?

As you go through your shelter looking for the places which look like they will provide the best shielding from gamma radiation, you should also look for ways to improve the shielding. Look for openings that can be covered up and for places where walls and ceilings can be thickened to cut down gamma penetration.

In the example shown in Fig. 19, p. 57, the radiation safety could be improved with a little effort. Earth could be piled up around the outside where the basement wall rises above the ground level. All but one or two basement windows could be sealed with boards or with cardboard and plastic and then covered with earth. The remaining windows may be needed for ventilation and should be baffled rather than sealed.

About 40-50 man-hours of labor would be needed for the improvements in the radiation safety of this shelter. Shovels, picks, and some carpenter's tools (hammers and saws) and supplies (nails, lumber, plywood, plastic sheeting, gloves, etc.) would be needed. People who are not used to manual labor should wear gloves from the start when picking or shoveling earth. Blisters are painful and can develop into serious infections, especially if antibiotics aren't available.

These efforts could improve the FPFs of this shelter by factors of 4 to 10. If the FPF of the safest location was about 25 before these improvements, the FPF could be 100 to 250 after. If the fallout is heavy, this improvement could mean the difference between life and death for the occupants.

Item 4: Are there openings to be baffled or covered to reduce the amount of radiation coming through them? Will these changes allow enough air to flow through to keep people from getting too hot when they are crowded?

Both the Shelter Manager and the RM will be involved with the problem of providing enough ventilation while maintaining the best radiation safety, as mentioned under Item 2, above.

In the basement shelter of Erskine Hall, sketched in Fig. 19, p. 57, all the windows except two should be sealed and covered with earth, as discussed under Item 3. Two windows are left uncovered to provide ventilation. These uncovered windows should be located on the side away from the direction that fallout is most likely to come from. If the wind usually blows from the northwest, these uncovered windows should be located on the south or east side. In Fig. 19, if the top of the figure is north, the uncovered windows should be the two windows near the corner in Room F. If the wind is blowing from the northwest when fallout is coming down, there may be less radiation buildup at the open windows on the southeast side.

These two uncovered windows should have a baffle or wall built around them with earth piled up on the outside to reduce the gamma radiation which shines directly into the shelter from fallout on the ground. If the bottom of the window is at ground level, the inside of the baffle should be dug down several inches below the level of the window as a trap for fallout particles. A trough or a pipe from the inside of the enclosed area to the outside ground level at a lower point is needed to provide drainage in case it rains.

Item 5. Are materials and tools handy which could be used for putting up improvised shielding after fallout arrives?



You may have improved the radiation safety of your shelter to the best of your judgment and capability, as discussed under Item 3. But after fallout arrives you may find with your survey meter that gamma radiation is shining through at some unexpected location. You should know where and what materials are available to stack up against or cover a wall, doorway, window, or portion of a ceiling to reduce the gamma penetration. Books, bricks, earth, wood, etc., may be used. Other materials and their shielding effectiveness are listed in Table 2, p. 23. If some of these materials are located outside the shelter, set up or ask the Shelter Manager to set up a work crew to move as much of it inside as possible before fallout arrives.

Item 6. Is there going to be a problem if a lot of people enter the shelter while fallout is coming down?

One of the problems which could develop is that the entrance to the shelter could be blocked by people just inside who have stopped moving for one reason or another. They may have stopped to brush off fallout particles, or, if the shelter is a large building, they may not know where to go.

If there is a possibility of problems at the entrances, one or two people should be selected to be receptionists at each entrance. The receptionists should see that people brush off fallout and shake outer garments if they come to the shelter after fallout begins to come down. Decontamination of people caught in fallout is described in Section 4.4.1, p. 67. The receptionists should also show people where to put outer garments from which fallout particles can't be shaken out easily, show them where to go in the shelter, sweep or vacuum up fallout particles whenever enough accumulates, and throw the swept-up particles outside.

The receptionists will need to wear dosimeters and must know how to read them. They should leave the entrance area and go back to the safest part of the shelter as soon as their dosimeters read 10 R. They may leave sooner if no people are arriving after fallout begins to come down.

The receptionists should set up places to store umbrellas, coats, and other outer garments if there are no convenient places to put these articles near the entrances. They should also have brooms and dustpans available.

It may be helpful to tape up sheets of paper which show the way to the safest places in the shelter. If no receptionists are at the entrances, it might be a good idea to tape up a sheet of paper near the entrances with information on how to decontaminate oneself.

Item 7. Are trips for water or to restrooms going to increase radiation exposure?

The RM should note where the drinking fountains, water outlets, and restrooms are located in his walk through the shelter. After fallout

has arrived, he will need to check the radiation levels at these locations. Some of them may have to be blocked off until the radiation decays to a safer level.

In nearly all public fallout shelters, there will be plenty of water for drinking, cooking, and flushing toilets as long as there are no nuclear detonations close enough to break water lines and damage storage tanks. Even if the electric power is knocked out by a distant nuclear explosion, there will still be water in the pipes and tanks which will flow by gravity. Water should be used as needed for drinking and sparingly for other purposes, but only when necessary, throughout the emergency.

In a nuclear war there is a possibility that the water supply might fail, so water should be stored in the shelter before fallout arrives. If the shelter runs out of water in a heavy fallout area, the RM may be faced with some difficult decisions and unpleasant situations. About two weeks' supply of water should be stored in areas where heavy fallout is expected. After about two weeks the radiation intensity even in the worst places will decay to levels where people can make emergency trips without the risk of radiation sickness or death. In areas where heavy fallout is expected and in the case of hot crowded conditions in the fallout shelters, a minimum of about 7 gallons of water should be stored per person, just for drinking.

Item 8. Where could dosimeters be mounted or hung? Are materials needed and available for mounting or hanging them?

In some shelters where the FPF is high and about the same everywhere, as in deep underground shelters, caves, and mines, only a few dosimeters need to be mounted or hung here and there where people will be located, to get an idea of what total exposures they are getting, if any. Tape, thumbtacks, nails, and string can be used to mount dosimeters.

In shelters where the FPF may change as you move from one location to another, you will need to issue one or two dosimeters to each shelter Unit Leader. The Unit Leader will then be responsible for estimating radiation exposure readings for the members of his unit. At certain times of the day or night, the Unit Leader may want to mount or hang one dosimeter in the vicinity of his unit and will then need materials for mounting or hanging it.

Item 9. Where can instruments, instrument supplies, flashlights, batteries, etc., be stored?

A central and secure location should be found for storing these items. In the shelter sketched in Fig. 19, p. 57, the closet under the stairs in Room G can be used. If you can't lock the door when you must leave, find someone to watch over the supplies. Don't let children play with the radiological instruments.

Item 10. Are there enough candles, lanterns, flashlights, and other light sources to provide light so you can move around and read your instruments if the power goes out?

As mentioned before, electricity may fail in many locations due to a wide-scale nuclear attack. Most of the shelters located in areas with the highest FPFs will also have the least daylight reaching them. When the power goes out, these shelters may be pitch black. Some light must be provided so people won't get hurt when they try to move around. You will need a light of some kind to read the radiological instruments. You should have your own flashlight or lantern so you can move around freely and read your instruments whenever necessary.

Item 11. Are printed forms or paper available for keeping records of radiation exposure?

The radiation exposure of each shelter occupant should be recorded every day and for every special trip that increases that person's exposure. A sample radiation exposure record is shown in Fig. 17, p. 52, and at the back of this handbook. If printed forms for this record are not available, ordinary notebook paper or stationery may be used. If no paper is on hand in the shelter and none is obtainable before fallout arrives, the records may be written on the walls or on whatever materials and surfaces are available.

Remember, the main purpose of the record is to limit the radiation exposure and to keep the individual from getting radiation sickness. If someone doesn't know what he's been exposed to, he won't know whether he's going to get radiation sickness if he wants to take a trip out of the shelter. He needs to know how much exposure he has so he can decide whether he can safely make a trip outside.

It will be useful to have a lot of paper to write and draw on in the shelter, not only for radiation records but for shelter sketches, messages, and bulletins. You will need a notebook, which we will call the RM Log, to keep a record of events. In this book you should enter the time and date and a brief description whenever explosions are heard or detected, when fallout arrives, when special measurements are made, when you have trouble with instruments, etc.

#### 4.2.3 Getting and Checking the Instruments

Each county may have a slightly different procedure for getting radiological instruments to the shelters, if they are not there already. In some counties the instruments may be delivered, but in most counties the RM (Radiological Monitor) will be expected to pick up the instruments for his shelter. If you are selected to be an RM after you arrive at the shelter, you may have to find out where the instruments are, and you may have to make a special trip to get them. Instructions on how to use the instruments may be given at the place where they are issued. If the RM has not used the instruments recently and no instructions are given, the RM should read Chapters 2 and 3 of this handbook before trying to operate them.

If available, there should be at least one dosimeter for each shelter unit (see Section 4.2.1, p. 51, "Organization of Shelter Population"), and one dosimeter each for the Shelter Manager and the RM. There should be one survey meter for approximately every 200 occupants in a shelter and one dosimeter charger with every survey meter. You should get one extra D cell battery for each survey meter and for each charger. If extra batteries are not supplied with the instruments and if there is time, go to a store and buy them.

An operational check on the instruments should be made to see if they work as soon as they are received, at the place where they are issued, if possible. Instructions for operational checks are given in Chapter 3 of this handbook.

When you have the instruments at the shelter, go through another operational check. Zero the dosimeters, if they haven't been zeroed already (see Section 3.4.2, p. 44, "Charging or Zeroing the Dosimeter"). If there is time, start a leak check on all dosimeters (see Section 3.4.3, p. 46, "Checking Dosimeters for Leaks").

Let the shelter manager know that you have the instruments and what condition they are in.

Keep the instruments in a secure place until they are put to use. If you can't lock them up, find someone reliable to watch over them.

#### 4.2.4 Informing the People in the Shelter about Radiation Exposure

Many people have a great fear of "invisible death" from nuclear radiation. There will be much anxiety among people in the shelter when it is known that they are getting radiation from fallout. Even if people are frightened, it is better not to hold back information. The policy of "what they don't know won't hurt them" has never worked with the American public.

When the presence of fallout radiation first makes a showing on the survey meter, the people in the shelter should be informed right away. If there are several people watching the survey meter, the news of fallout radiation will travel very quickly through the shelter.

In order to let people know what the radiation levels are, you should select at least one place in each small or medium-sized room where people are sheltered (more places in large rooms) to mount a sheet of paper on which the survey-meter readings taken near the paper will be written periodically. A sample sheet is shown in Fig. 20. This sheet and the measurements will be discussed again in Section 4.4.3, p. 75.

If there is time enough before fallout arrives, each shelter Unit Leader should be shown how to read a dosimeter. Each Unit Leader should be encouraged to read the first chapter of this handbook, if they

## SURVEY-METER READINGS

LOCATION: 1. CENTER, NORTH WALL, ROOM G, ERSKINE HALL

Date	Time	Reading (R/hr)	Comments	Date	Time	Reading (R/hr)	Comments
5 JULY	1020	0.10	FIRST FALLOUT READING	5 JULY	1630	2.75	
"	1030	0.18		"	1645	3.0	CLIMBING AGAIN
"	1045	0.50			1700	3.5	
"	1100	0.87			1715	4.0	
"	1115	1.2			1730	4.5	
"	1130	1.55			1745	5.0	
"	1145	1.95			1800	5.5	
"	1200	2.3			1815	5.75	
"	1215	2.75			1830	6.0	
"	1230	3.0			1845	6.0	
"	1245	3.25			1900	6.2	
"	1300	3.25	LEVELING OFF		1915	6.2	LEVELING OFF
"	1315	3.25			1930	6.2	
"	1330	3.25			1945	6.0	FALLING AGAIN
"	1345	3.25			2000	6.0	
"	1400	3.25			2015	5.75	
"	1415	3.25			2030	5.75	
"	1430	3.25			2045	5.5	
"	1445	3.15	FALLING		2100	5.5	
"	1500	3.10	EXPLOSION HEARD				
"	1515	3.05					
"	1530	3.0					
"	1545	2.95					
"	1600	2.9					
"	1615	2.85					

Fig. 20. Sample survey-meter readings at location 1 in make-believe Erskine Hall.

haven't read it already. If there is only one copy, the fastest readers should be the first ones given the handbook to read.

#### 4.3 Watching for Fallout to Arrive

People may find out that a nuclear attack is about to happen or is on its way by announcements on the radio or TV, by sirens or other warning devices, or by word of mouth. When a nuclear weapon explodes anywhere within several hundred miles, there will be many signs to indicate it. By that time people should be on the way to their shelter if they are not already there. No one should be outside or very far from a shelter when fallout begins to come down.

A nuclear explosion several hundred miles away can cause an electromagnetic pulse (EMP) which may burn out the transmitting capability of some radio and TV stations and also knock out some telephone circuits. The EMP may also affect power lines, causing momentary blackout or flickering of lights. It may cause a lot of static similar to lightning static in AM radios and may burn out FM radios or TVs with large antennas. Nuclear explosions near power lines or power stations may cause widespread power blackouts. Nuclear explosions produce a brilliant flash and glow in the sky which may be seen over 50-100 miles away in the daytime if the weather is clear and much farther at night. Staring at the flash may cause eye damage even if the burst is far away. A shaking of the ground as in a mild earthquake will follow within a few minutes.

The following procedure applies to shelters that are located at least 25 miles away from a possible target for a nuclear weapon. After nuclear explosions have taken place with noticeable effects in or near the shelter, or when notified by the EOC, the RM (Radiological Monitor, for whom the following is written) should take the survey meter outside or by an outside window (on the windward side if possible) and watch for the arrival of fallout. If the FPF of your shelter is high and the fallout is light in your area, your survey meter may not show that fallout has arrived if you keep the meter at the safest place in your shelter. It is necessary to know when fallout has arrived, even if it is light, so that exposure control measures can be started.

If you go outside, keep fallout particles from getting in your clothes and on your skin and hair. Carry an umbrella and wear a hat if available. You may wish to enclose your survey meter in a clear plastic bag, if available, to keep it from getting contaminated. You should carry a dosimeter in a breast pocket or on a chain or string around your neck. You should take along a transistor radio or, better yet, a two-way radio, if available, to keep yourself informed on the situation around you. If it is nighttime, you should take a flashlight along even though the power may be on and the area may be brightly illuminated at the time you start your watch. If you expect fallout to arrive within the hour, zero your survey meter and leave it on with the range-selector

switch turned to "X0.1." If you don't expect fallout to arrive until after an hour or more, leave the survey meter turned off to save the batteries. You may want to turn it on every ten or fifteen minutes just to check the situation.

If fallout arrives from a ground explosion between 25 and 75 miles upwind, depending on the yield of the weapon, you will probably notice its arrival by the sound of gritty particles striking the window or surfaces around you. You may hear these gritty particles striking for many seconds before the needle on your survey meter begins to climb. When the needle reaches 0.1 R/hr you should note the time, enter the shelter, decontaminate yourself (see Section 4.4.1, p. 67) if you have been outside, record the reading, time, and date in your RM Log, and tell the Shelter Manager and occupants that fallout has arrived.

Some people may be working outside the shelter to improve its radiation safety, or they may be carrying shielding materials into the shelter up to the last minute before fallout arrives. They may become aware of the arrival of fallout by noticing the gritty particles striking their skin, by hearing them strike nearby surfaces, or by seeing the buildup of particles on surfaces. These people should then go inside the shelter and decontaminate themselves. If they do not notice the arrival of fallout, you, the RM, should tell them that the arrival of fallout has been detected by the survey meter.

If fallout comes to your shelter from many large ground bursts 100 miles or more upwind, the fallout may not arrive for many hours. The fallout may be hazardous even though it may arrive as late as 24 hours after the explosions. You may decide not to set up your own watch for fallout for that length of time if your shelter has good two-way communications with the local EOC. If the people in your shelter feel they can rely on the local EOC, then they may decide to depend on the announcements from the EOC to let you know how fast the fallout is coming to your shelter. These announcements should come at least every half-hour or hour from your EOC, depending on the situation. When it appears that fallout might arrive at your shelter in two or three hours, you should take the survey meter to a window or outside and begin to watch for fallout, as described above.

The people in the shelter may want to have their own lookout for fallout, even though the EOC may seem to be reliable. If you expect the fallout to take a long time to arrive, you should arrange for people to take turns or shifts in watching for its arrival.

When fallout arrives from distant explosions, you may not notice it as much as you would notice the fallout from closer explosions. The particles may be so small that you may not feel them as they land on your skin. The climbing of the needle on the survey meter may be the only indication that fallout from distant explosions has arrived.

The fallout is carried most of the way to its destination by winds at high altitudes. On some days the wind at high altitudes may be blowing in a different direction from the wind on the ground. Under these

conditions you might think that fallout from a particular nuclear explosion will not come your way because the wind on the ground where you are is not coming from the explosion. In this situation the fallout might arrive at your shelter contrary to your expectations. The direction that the particles are blown by the surface winds may make it seem that they are coming from the wrong direction. Unless you have some positive information on the direction the fallout is being carried, you should not make any assumptions about where it will come down.

#### 4.4 While Fallout Is Coming Down

##### 4.4.1 Decontamination of People Caught in Fallout

Fallout arriving within a few hours after a nuclear explosion is highly radioactive. If it collects on the skin in large enough quantities it can cause beta burns (see Section 1.5.2, p. 18, "Symptoms of Radiation Injury").

People who are caught outside in fallout should brush fallout particles off themselves and shake out their outer garments as soon as they get inside the shelter. Some people may be carrying umbrellas and wearing raincoats to keep the fallout particles off their skin and hair. If people have not taken such precautions, they should try to get the fallout particles off their skin and out of their hair and clothing as much as possible before going further into the shelter, but they should not block the entrance so other people can't get in. It is more important that people get into the shelter than it is to get every speck of fallout off every person before they go further into the shelter. Fallout particles which are carried into the shelter can be swept up and thrown outside.

If there is a possibility of a blockage at the entrances because of a lot of people coming to the shelter after fallout arrives, one or two receptionists should be assigned to each entrance to supervise the decontamination. Each receptionist should wear a dosimeter. They should leave the entrance area as soon as their dosimeters show that they have been exposed to 10 R of radiation. If only one or two people come every few minutes to the shelter, the receptionists should go back to the safer parts of the shelter. Instructions for decontamination and directions to the safest shelter locations should be printed on sheets of paper and taped or tacked up in places where incoming people can easily see them.

Most fallout particles will be like grains of fine dark sand. These particles can be easily brushed off from dry surfaces. The particles can be removed from tightly woven fabrics and rainwear by lightly shaking them.

Loosely woven outer garments such as knitted sweaters, shawls, and scarves may hold fallout particles even after a hard shaking. These



garments should be stored in a special place set aside for them until they can be washed. After they are washed they will be perfectly all right for normal use. The fallout particles will come out in the wash. The fallout particles or the radiation will not damage the fabric or make it radioactive.

Fallout particles may stick to moist or oily surfaces, including sweaty or oily skin or hair. These surfaces should be carefully wiped or washed off. If contaminated hair cannot be washed, it should be thoroughly brushed or combed, with frequent shaking and wiping of the hair and also of the brush or comb.

It is not necessary to get the last speck of fallout out of the clothing or hair or off the skin. A few grains of fallout carried by each person into the safest parts of the shelter will produce no noticeable increase in the radiation hazard and will not be detectable by the radiological instruments. Daily sweeping of the shelter for hygienic reasons will get rid of most fallout particles which may be carried into the shelter even though persons may go through decontamination procedures.

The reception area should be organized so people can shake out their outer garments without getting the particles on people around them. After they have shaken out their clothing and wiped off their exposed skin, they should move further into the shelter and sweep the dust off their shoes with a brush or broom. If the shoes are caked with mud or dust, they should be left in the reception area.

Because the fallout particles will fall down to the floor, decontamination of a person should begin with the head and end with the feet. Brushing off or removing the shoes will be the last step of decontamination before a person enters the safer parts of a shelter.

#### 4.4.2 Finding the Places with the Lowest Radiation Levels in the Shelter

After the announcement is made to the people in the shelter that fallout has begun to come down outside, you (the RM) should use the survey meter to find the places which have the lowest radiation levels. The people in the shelter should be gathered at the locations which are estimated to have the lowest radiation levels. It should be explained to the people, or at least to the shelter Unit Leaders, that these locations were chosen on the basis of estimates and that places with lower radiation levels might be found by taking readings with the survey meter.

You should have a sketch of the shelter with locations marked where you plan to take readings of the radiation levels. These readings should be taken near walls, posts, or columns on which you can tape up a sheet showing your readings. An example is shown in Fig. 20, p. 64. At this time, when you are trying to find the safest places in the shelter

as quickly as possible, you should take readings only in those locations where you estimate the lowest radiation levels will be. For example, if you are in a basement shelter you should not take readings on the first floor at this time. If you are in a skyscraper shelter, there is no need to take readings at this time at locations near an outside wall. The first survey should be spread out to get a general picture of the best shelter areas. Follow-up surveys should then be made to get a detailed picture of radiation levels in the areas where people are finally sheltered.

Your general survey of radiation levels with the survey meter should be made as soon as possible after the gamma radiation reaches levels which can be detected with the meter. If you find a location where the radiation levels read at least 10% lower than the place where people are sheltered, the Shelter Manager should be told, and people should be moved to the safer location at once.

While fallout is coming down, the radiation levels may be climbing fast. Inside your shelter at the location which you have estimated to be the safest, your survey meter needle may be climbing one to five smallest divisions on the "X0.1" scale every minute. If you are planning to compare the readings at several locations, the reading at the final location may be quite a lot higher by the time you get to it than it was when you started taking readings. You will not be able to tell whether that higher reading results from a lower FPF or from an increase in radiation levels at all locations of the shelter. The readings would have to be taken in both places at the same time to show which location had the lowest radiation level. You can only be at one place at one time!\*

In order to get a fair comparison of the radiation safety between different locations while the radiation levels are climbing rapidly due to the buildup of fallout, you will need to use the time-averaging method described below. You should not plan to wait to make your measurements until the radiation levels stop climbing so fast, because it might take several hours before the fallout stops coming down.

The time-averaging method is used to compare the radiation levels between two or more locations in a shelter when the radiation levels are climbing rapidly and when you have only one survey meter. If only two locations are to be compared and only a few seconds are needed to get from one location to another, the time-averaging method need not be used. The readings obtained at the two locations may be compared directly in that case.

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\*If your shelter has two or more survey meters and two or more RMs, you may check as many locations simultaneously as you have survey meters, with readings synchronized by timepieces showing seconds or by the use of two-way radio communication between the RMs. The meters should be compared at one location (identical radiation levels) before and after the measurement (the instruments may drift) to make sure they read the same or to compensate for different readings.

The time averaging method is a way to estimate what the approximate radiation levels were at several locations at one particular time. It consists of taking readings at different locations before and after one particular time and then averaging those readings to get the reading at that particular time.

If only two locations are to be compared, say locations 1 and 2, a reading is first taken at location 1. Then one minute later a reading is taken at location 2. After another minute, a reading is taken at 1 again. The two readings taken at 1 are then averaged (add them and divide by two) and compared with the reading at 2.

If three locations are to be compared, at locations 1, 2 and 3, readings are taken one minute apart at 1, 2 and 3 and then at locations 2 and 1 again, in that order. The order of measurements, 1-2-3-1, must not be changed. The two measurements at 2 are taken one minute before and one minute after the measurement at 3, the middle or central measurement. The two measurements at 1 are taken two minutes before and two minutes after the central measurement. The two readings at 1 are averaged, and the two readings at 2 are averaged to give approximations of what the readings would have been at those locations at the same time that the reading at location 3 was taken.

To use the time averaging method you will need a wristwatch or clock which shows seconds as well as minutes. You should have an assistant to help you push through crowds of people, watch the time, help keep track of the measurements, etc.

Remember that the survey meter does not respond instantaneously to the radiation it is measuring when the range selector switch is turned to "M-1." You may need to allow a few seconds at each location for the needle on the meter to reach its final reading. Do not move, fiddle, or rotate the survey meter while the needle is settling down.

The survey meter should be held at about three feet above the floor or at about waist level and about two feet away from the body when making measurements. If you are making a measurement in a room full of people, it is important that all the people sit or lie down on the floor while you make the measurement. If a lot of people are standing, they will shield some of the gamma radiation from your instrument. Your survey meter will then show a lower reading than it would if people were sitting or lying down or if the room were empty. If you used this reading to compare with readings at other locations which are empty, you could come to the wrong conclusion with the people and it is safer, although it may actually be more tedious,

If you are going to compare the readings at several locations, start your time starting where you think the reading should be the lowest. This location should be where the people are located. Begin the readings when the needle reads about 0.1 R/hr. in the safest location. If you start in another location, you may find that by the time you get to the estimated safest location the radiation level may still

not be high enough to read on the meter. You will then have to repeat the measurements later.

An example of the time-averaging method is shown in Table 4. The RM for the shelter in make-believe Erskine Hall, introduced under Item 1, Section 4.2.2, p. 56, used the method to compare the radiation safety of the seven rooms in the basement. The locations where he made the measurements are shown in Fig. 21. People were packed together in Room G, where he made the first and last readings. The choice of locations where readings were taken and the order in which they were taken was made before fallout arrived. As soon as the first fallout reading was made at location 1 at 1020 hr,\* the time to begin the series of measurements was chosen to be 1030 hr. Ten seconds was allowed for the survey-meter needle to settle down. The first reading was taken at 1030 hr and the last reading at 1042 hr. Readings at location 1 were made six minutes before and six minutes after the central reading was taken at 1036 hrs at location 7. Readings at location 2 were made five minutes before and five minutes after the central reading at location 7, and so on. The two readings made at each location (except where the central reading was made) were added and divided by two to give an estimate of what the readings would have been at those locations at the same time the central reading was taken (1036 hr) at location 7. These time averages are listed at the bottom of Table 4. From these readings it was confirmed that Room G (location 1) provided the best radiation protection in the basement of Erskine Hall. Note that the readings at locations 1 and 2 more than doubled between the first and second readings.

If a sudden squall or weather front with high winds and heavy rain strikes your shelter while you are in the process of taking readings for time-averaging, you may need to disregard your measurements and wait until the weather settles down before you try the readings again. You may not be able to tell whether a decrease in reading from one room to another results from the second room being safer or from a decrease in radiation level because fallout particles are being blown and washed away. The reading may change because of a combination of these two causes.

You should compare the radiation levels between the different areas every twelve hours, or whenever anything takes place that might move the fallout particles around, such as a heavy rain or windstorm. After the fallout has stopped coming down, it won't be necessary to use the time-averaging method for making these comparisons.

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\*24-hr time is used to prevent confusion between AM and PM. This time notation is used by airlines and the military services. The first two digits indicate the hour of the day, starting with zero at midnight, and the second two digits indicate the minutes after the hour. The 24-hr time in the afternoon is obtained by adding 12 to the 12-hr time in the afternoon (hours past noon). Thus 1:10 PM (ten minutes past one) becomes 1310 hr, 2:20 PM becomes 1420 hr, etc.

Table 4. An example of the use of the time-averaging method to compare the radiation safety between basement rooms of Erskine Hall when radiation levels are rising rapidly

A. Measurements

Local time	Location number <sup>a</sup>	Survey-meter readings (R/hr)
1030	1	0.18
1031	2	0.34
1032	3	0.38
1033	4	0.40
1034	5	0.70
1035	6	0.48
1036	7	0.52
1037	6	0.55
1038	5	0.92
1039	4	0.65
1040	3	0.67
1041	2	0.72
1042	1	0.45

<sup>a</sup>Fig. 21 shows where these numbered locations are situated in the basement of Erskine Hall.

B. Time averages

Location 1	Location 2	Location 3	Location 4	Location 5	Location 6
0.18	0.34	0.38	0.40	0.70	0.48
0.45	0.72	0.67	0.65	0.92	0.55
<u>2)0.63</u>	<u>2)1.06</u>	<u>2)1.05</u>	<u>2)1.05</u>	<u>2)1.62</u>	<u>2)1.03</u>
0.315	0.53	0.525	0.525	0.81	0.515

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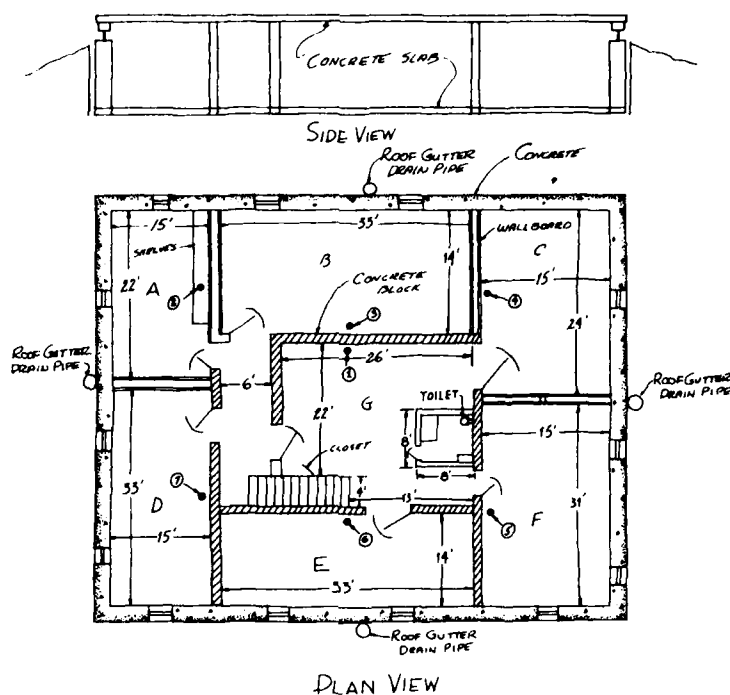


Fig. 21. Locations of survey-meter readings for time-averaging in the basement of Erskine Hall are shown by dots and are identified by numbers in circles.

#### 4.4.3 Finding and Covering Up "Leaks" in Gamma Shielding

After the safest locations have been found in the shelter and the people have moved there if they weren't there already, you should use the survey meter to make detailed measurements of the radiation levels in and around the area where the people are located. Remember that people's bodies will shield gamma rays; so people must sit or lie down in the area while you are taking a reading there. Take readings in the corners of rooms, at the center of walls, and near openings and doorways. You may find some areas where the radiation levels are more than twice as high as at other areas. There may be a thinner wall, a door, a hall, or some type of opening through which additional gamma radiation is "leaking" into the shelter.

The shielding provided by your own body can help you find the gamma radiation leaks in a horizontal direction. The measurements you have made so far have been made with the survey meter held out from the body about two feet, so your body shielding will have less interference with the reading. The survey meter responds to gamma rays equally from all directions. If gamma rays come in greater numbers from one particular direction, you can't detect the direction just by pointing the instrument toward it. But you can use the shielding provided by your body to reduce the radiation coming through your body toward the survey meter.

To find a gamma leak, hold the survey meter tightly against your stomach and face the area where you expect extra gamma radiation to be coming from. If the range-selector switch is turned to "X0.1," wait ten seconds before you take a reading. This reading will be called a "front" reading. Then turn around so your back faces the leak, and with the survey meter still held tightly against your stomach, take another reading. This reading will be called a "back" reading. If there is more radiation coming from the direction you faced for the first reading than from the opposite direction, the front reading will be higher than the back reading. As you slowly turn around, you may notice that the meter needle goes through the lowest reading when you are facing a particular direction. The radiation leak is then at your back. Repeat these "front-to-back" readings at different places and directions until you have a fairly good idea of where the extra radiation is coming from.

After you have found a radiation leak, tell the Shelter Manager. A work party should be organized to build a gamma barrier to cover up the leak. If you had the time and opportunity, you should have gathered together materials for this purpose before fallout arrived, as discussed under Item 3 in Section 4.2.2, p. 58. Work on the construction of this barrier should begin as soon as possible, before the radiation climbs to higher levels. The barrier can be improvised from any materials on hand. If you have lumber, nails, and carpenters' tools available and have hauled piles of earth or sand into the shelter before fallout arrived, you may be able to construct a very good barrier. Stacks of bricks will also make good barriers. If these materials aren't available, furniture, books, magazines, newspapers, etc., may be used.

While you are searching for gamma leaks or while the barrier is being constructed, you must not forget to break away every 15 minutes and take the regular readings which tell whether the radiation levels are rising or falling. As mentioned before, these readings should be written on a piece of paper or on a form as shown in Fig. 20, p. 64, and taped or tacked to a wall or post near the place where the reading was made.

After the barrier is constructed you should take several "front-to-back" readings to see whether the radiation leak has been covered up. If the front and back readings are about the same, the barrier has made the shielding in that direction as good as in other directions. If the front reading is less than the back reading, the barrier has improved the shielding in the leak area to be better than the shielding for the rest of the shelter. If the front reading is still higher than the back reading, the barrier is not heavy or thick enough or may have missed the area through which extra gamma radiation is passing. More work on the barrier will be necessary.

Again, let us look at Erskine Hall for an example. The shelter sketch is shown in Fig. 21, p. 73. In making a detailed survey of Room G the RM found readings in two places which were 15-30% higher than at other places in Room G. One location was by the closet under the stairs. The other location was by the open door to Room F.

The reading by the stair closet was about 15% higher than elsewhere. The radiation was assumed to be coming from above, through the stairways. The Shelter Manager, RM, and Unit Leaders decided not to pile material on the stairs because the occupants would then have trouble getting out if there was a fire. Instead, they blocked off an area by the closet and planned to rotate people in and out of that area so the radiation dose would be evenly spread out among people beyond childbearing age, those in radiation sensitivity category 6.

The reading by the door to Room F was about 30% higher than elsewhere. In the time-averaging readings, Room F (location 5) was found to have a higher reading than the other rooms, as shown in Table 4, p. 72. This higher reading was expected, because in improving the radiation shielding of the shelter, all the windows around the basement had been covered up except two in Room F. These two open windows were considered to be absolutely essential to provide cooling for the people packed in Room G. Fresh air was coming in from those windows, passing through the open door to Room G, and flowing out the door by the stairs.

After examining the sketch of the floor plan, it was decided that a hole could be knocked in the wallboard partition between Rooms C and F and the door between Rooms C and G could be left open. The door between Rooms G and F could then be closed and covered with a barrier.

The hole between Rooms C and F was made on the far side from the door, by the outside wall, so the gamma rays from the two open corner windows would not have a direct open path to the door between Rooms C and G. The door between rooms F and G was closed, and a stack of bricks was built up in front of it.

These measures reduced the radiation in Room G by the door to Room F to levels that were about the same as elsewhere in the room (except by the stairway closet). Ventilation became much better for the people along the north half of the room, but the people in the hall leading to Room F soon complained about their ventilation being cut off. The bricks in front of the door to Room F were restacked so there were one to two-inch gaps between the bricks on the bottom four layers. The door was propped open a few inches so air could come through and flow through the gaps left between the bricks. Another wall of bricks, only six layers high, was constructed about six inches back from the door-high stack of bricks, to block off gamma rays coming through the gaps.

#### 4.4.4 Gamma Shielding by People

In Table 2, p. 23, the human body is listed with a density of 0.4 relative to concrete. The shielding effect of human bodies can be used to provide extra protection. It would be of particular benefit to those people with the greatest sensitivity to radiation, those in radiation sensitivity categories 1, 2, and 3, namely, children and pregnant women. If the estimated or projected radiation exposures look as if they may become high enough to cause radiation sickness and other ways to decrease



or avoid radiation exposure are not possible, this method could be used. It would be expected that this extreme measure of providing shielding would be used only during the first 24 hours after fallout arrives, when the radiation hazard is by far the most severe.

Most of the people in most shelters will be sitting or reclining on the floor most of the time. More gamma radiation will be blocked off if the people are standing up, because their bodies will then shield some of the gamma rays coming from the ceiling as well as those coming from the walls. Some people with less sensitivity to radiation, those in radiation category 6, may stand up in shifts and form circles two or three layers deep around the grouped children, mothers with infants, and pregnant women. The mothers with infants and pregnant women should sit on the floor. Some should wear dosimeters. If beds, desks, or tables are on hand, children and infants may be placed under them, and older people should then sit or lie on the top to provide additional shielding for the children from overhead radiation. It may be necessary to break up some of the shelter units temporarily while these shielding measures are being taken.

If chairs are available, they may be arranged to encircle the area to be shielded. Some people may provide a circle of partial shielding by sitting in the chairs facing outwards. Others may improve the shielding by standing up in two or three layers inside the circle of chairs. The survey meter should be used to find the arrangement of people which will provide the best shielding.

The RM may verify this shielding effect by taking the survey meter into the middle of a room full of people who are standing up and reading the meter at different levels. In basement shelters, where no gamma radiation comes up through the floor, the survey meter reading at the floor might be as much as ten times lower than the reading at waist height at the wall. The radiation may even be undetectable. In high-rise shelters where much of the gamma radiation comes in horizontally through the walls and some comes up at different angles through the floors, this effect won't be as dramatic.

#### 4.4.5 Keeping Track of Everyone's Radiation Exposure (Group Dosimetry)

The radiation hazard will be worst throughout the first 24 hours after each fallout cloud arrives. It is important to start keeping track of everyone's radiation exposure right away, as soon as fallout begins to arrive. In most shelters the radiation levels will be different as you move from one place to another. In these shelters each unit leader should have a dosimeter. The readings on the Unit Leader's dosimeter will be used to fill out the radiation exposure record of each member of the unit. For this reason every member of the unit should stay close to the leader, especially during the first 24 hours after fallout arrives. This method of estimating individual exposures is called group dosimetry.

If any member of the unit needs to make an urgent trip to some area where the radiation level is higher and for such length of time that the person's radiation exposure might be a few roentgens higher than the rest of the unit, some special arrangements should be made. The Shelter Manager and RM should be consulted if the trip is unusual. An extra entry should be made on the individual's radiation exposure record for such trips.

Trips to restrooms and drinking fountains in areas of higher radiation levels should be limited in number and length of time. The Unit Leader should make about the same number of trips at about the same times and the same lengths of time as made by other unit members. The dosimeter should be worn by the unit leader on these trips to get an idea of how much exposure is received during these trips. If some members need to make additional trips, the extra exposure should be estimated by the Unit Leader, with help from the RM if necessary, and entered on the members' radiation exposure records.

A dosimeter hung on the wall or post at eye level or higher will show a higher radiation exposure than a dosimeter carried on a person in the same area. The person's body shields the dosimeter from some of the gamma radiation. If the person wearing the dosimeter is surrounded by many people who are standing up, the reading on that person's dosimeter will be even lower because of the gamma shielding provided by the people's bodies.

During the first 24 hours after fallout begins to come down, entries should be made every 4 hours in each person's radiation exposure record. The Unit Leader should check each entry on each record kept in his unit. The RM should spot-check records throughout the shelter and look for entries which seem to be too high or too low. Such entries may be due to faulty instruments, or they may be due to shielding conditions which the RM should know about. It is important that these situations be corrected as soon as possible.

Sample radiation exposure records from Erskine Hall are shown in Figs. 22 and 23. The radiation exposure record in Fig. 22 shows what a dosimeter would read if it were mounted at location 1, where survey meter readings were taken for Fig. 20, p. 64. The radiation exposure record taken from dosimeters clipped to the clothing of adults on the edges of Room G would have entries which may be less than 75% of the entries in Fig. 22, due to the shielding effect of their own bodies and others. The entries on records of those in the interior of the room would be even lower.

In Fig. 23 the radiation exposure record is shown for John Doe, an infant. His radiation sensitivity category is 2, as listed in Table 3, p. 53. This record was maintained by his father, James Doe, who was made the leader of the shelter unit in which the Doe family was placed. The radiation levels in Erskine Hall started to climb a second time at 1645 hr on July 5, 1989, as shown by the survey-meter readings in Fig. 20, indicating the arrival of another cloud of fallout. By 1745 hr the

Home Address

Social Security No.

Shelter Address *ERSKINE HALL*

Name of Shelter

Unit Leader

Rad. Sensitivity

Category \_\_\_\_\_

Hour and Date	Added Exposure (R)	Total Exposure To Date	Comments
1400			
5-7-89	8	8	FALLOUT BEGAN AT 1009
1800			
5-7-89	14	22	
2200			
5-7-89	23	45	
0200			
6-7-89	15	60	
0600			
6-7-89	12	72	
1000			
6-7-89	9	81	END OF FIRST 24 HR
1000			
7-7-89	35	116	
1000			
8-7-89	19	135	
1000			
9-7-89	14	149	
1000			
10-7-89	10	159	
1000			
11-7-89	8	167	
1000			
12-7-89	7	174	END OF FIRST WEEK
1000			
13-7-89	6	180	
1000			
14-7-89	5	185	
1000			
15-7-89	4	189	

FRONT SIDE

[illegible]

BACK SIDE

Fig. 22. Sample dosimeter readings at location 1 in make-believe Erskine Hall.

Hour and Date	Added Exposure (R)	Total Exposure To Date	Comments
1400			
5-7-89	6	6	FALLOUT BEGAN 1009
1800			
5-7-89	10	16	SPECIAL SHIELDING BEGUN
2200			
5-7-89	7	23	
0200			
6-7-89	5	28	
0600			
6-7-89	4	32	
1000			
6-7-89	3	35	UNIT SHIELDING BEGUN
1000			
7-7-89	18	53	
1000			
8-7-89	10	63	
1000			
9-7-89	7	70	
1000			
10-7-89	5	75	
1000			
11-7-89	4	79	
1000			
12-7-89	3	82	END OF FIRST WEEK
1000			
13-7-89	3	85	
1000			
14-7-89	3	88	
1000			
15-7-89	2	90	

FRONT SIDE

[illegible]

BACK SIDE

Fig. 23. Sample radiation exposure record for the fictitious John Doe, as filled out by his father. The estimated effect of human shielding may be seen by comparing these entries with the readings of an exposed dosimeter shown in Fig. 22.

radiation level had reached 5 R/hr at location 1 and was still climbing. It was decided that human body shielding would be used to protect those in the first three radiation sensitivity categories. This special shielding, involving all the people in the shelter, began at 1800 hr, as shown on the radiation exposure records in Fig. 23, and reduced John Doe's exposure to less than half of what it would have been without this special shielding. On the second day, 24 hours after fallout arrived, special shielding was terminated, but partial shielding for John Doe was provided by the members of his shelter unit. The next 13 entries were made on a daily basis instead of every four hours. On July 18 the occupants of Erskine Hall were relocated to a shelter in an area with much lighter fallout.

#### 4.5 After Fallout Has Stopped Coming Down

##### 4.5.1 Forecasting Radiation Exposure

When the survey meter readings level off at a high reading and then begin to decrease, the fallout from that particular cloud at your location has almost ended. If no more fallout clouds arrive, the radiation levels will continue to decrease rapidly.

The highest radiation exposure at a given place in a shelter will accumulate during the first 24 hours after fallout arrives. After these first 24 hours have passed, there are two general rules which can be used to forecast the radiation exposure, as follows:

Rule 1: The radiation exposure at a given place during the entire week following the arrival of fallout will rarely be more than 2.5 times the exposure during the first 24 hours.

Rule 2: The radiation exposure at a given place during the entire month following the arrival of fallout will rarely be more than 3-3/4 times the exposure during the first 24 hours.

If the fallout comes from distant ground bursts and doesn't arrive at your shelter until 24 hours or more after the explosions, the numbers in Rules 1 and 2 may be slightly greater. For example, if the fallout takes about 36 hours to get to your shelter, the number 2.5 in Rule 1 will be increased to 3.0 and the number 3-3/4 in Rule 2 will be increased to 4.5. If the fallout takes about 48 hours to get to your shelter, the corresponding numbers will be increased to about 3-1/3 and 5-1/3, respectively. When the fallout takes a long time to arrive, the radioactivity will have decayed a great deal. If the fallout comes from a large number of ground bursts of large-yield weapons, as might take place on military targets, the fallout may still be hazardous even though it may take 48 hours to arrive at your shelter.

If the fallout comes from closer ground bursts and arrives at your shelter in 12 hours or less after the explosions, the numbers in Rules 1

and 2 will be less. More than half of the total exposure in a week will accumulate in the first 24 hours after fallout arrives. The number 2.5 in Rule 1 will be decreased to between 1-1/2 and 1-3/4, and the number 3-3/4 in Rule 2 will be decreased to between 1-3/4 and 2-1/2.

Exposure forecasts can be made using the 7-10 rule described in previous handbooks when fallout results from only one nuclear weapon, when the time of its explosion is known fairly well, and when there are no weathering effects. These circumstances are unlikely in a modern full-scale nuclear war.

The general rules given above can be used to make forecasts for the possibility of radiation sickness among a group of people in a given shelter. If the radiation exposure of an average adult is 60 R or less at the end of 24 hours after fallout arrives and that person remains in the same place, that person's accumulated radiation exposures will usually be less than 150 R in one week and less than 225 R in one month, providing no additional fallout arrives. According to the Penalty Table (next section), that person should require no medical care in the first week, but the exposure in a month would exceed the limits set in the Penalty Table for not requiring medical care.

If it appears that the radiation exposure of average adults is going to be more than 60 R at the end of the first 24 hours after fallout arrives at the shelter, the local EOC should be notified. Some emergency action may be possible which will reduce the accumulated radiation exposure and thus prevent radiation sickness among these people.

Again, let us look at the made-up example provided by Erskine Hall. The radiation exposure record for a dosimeter mounted at location 1 is shown in Fig. 22, p. 78, and the survey-meter readings for that location are shown in Fig. 20, p. 64. The first detection of fallout was made outside the shelter at 1009 hr, July 5, 1999. It was estimated that this fallout resulted from many large yield ground bursts on military targets about 250 km (150 miles) upwind during the night before, at around 2100 hr on July 4, 1999. The radiation level from this fallout reached a maximum value at around 1330 hr, July 5, indicating that just about all the fallout destined for Erskine Hall from these explosions had reached the ground by this time. The fallout took 13 hours to reach Erskine Hall and was therefore considered to be "old" fallout. It kept coming down for about 3-1/2 hours.

A distant explosion was heard at 1500 hr, July 5, in the direction of a city located about 50 km (30 miles) upwind. The fallout from this explosion started to arrive at Erskine Hall at about 1645 hr, an hour and 45 minutes after the explosion was heard. This fallout was considered to be "fresh" and was more radioactive than the "old" fallout from the distant explosions. Being fresher, it would decay faster. This fallout kept coming down for about 2-1/2 hours and added to the radiation levels which were already there from the old fallout.

At the end of the first 24 hours after fallout arrived, at 1000 hr on July 6, the accumulated radiation exposure by the dosimeter at location 1 was 81 R, as shown in Fig. 22, p. 78. After one week, the accumulated radiation exposure was 174 R, 2.15 times the exposure during the first 24 hours. After one month, it was 226 R, 2.79 times the exposure during the first 24 hours.

#### 4.5.2 The Penalty Table

Each person can tolerate a certain amount of sunshine on bare skin in an afternoon without getting a painful sunburn. Similarly, each person can be exposed to a certain amount of whole-body gamma radiation within a certain period of time without getting sick. The Penalty Table\* (see Table 5) shows in row A what exposures might be received by an average adult without requiring medical care, when the exposure is spread out over different periods of time. For small children and infants weighing less than about 50 lb, the numbers in row A should be multiplied by 2/3.

Table 5. The Penalty Table.

An average adult will not need medical care when the whole body is exposed to the quantities of radiation listed in Row A when the exposure is spread out over the listed periods of time. Rows B and C are intended to be used for making decisions on performing urgent missions which may require extra radiation exposure.

Medical care will be needed by--	Accumulated radiation exposure (R) in any period of		
	a	b	c
	One week	One month	Four months
A NONE	150	200	300
B SOME (5 percent may die)	250	350	500
C MOST (50 percent may die)	450	600	---

The use of the Penalty Table for making decisions will be discussed in the next section.

For most shelter occupants, the exposures in Row A should not be exceeded. If the radiation levels reach 10 R/hr in the shelter and

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\*This table is taken from Radiological Factors Affecting Decision-Making in a Nuclear Attack, National Council on Radiation Protection and Measurements, Report No. 42.

continue to climb, it is possible that the accumulated exposure in one week will be greater than 150 R. In this case the local EOC should be notified. Some emergency action may be possible which will reduce the accumulated radiation exposure and thus prevent radiation sickness in the shelter.

#### 4.5.3 Use of the Penalty Table as a Guide for Operations

The Penalty Table was developed to provide a simple guide when decisions need to be made which may involve some risk. The choice of the numbers was based on judgment derived from extensive clinical radiotherapy experience, pathological studies of radiation-accident victims, and laboratory experience with numerous large and small animals. There is no directly applicable disaster or laboratory experience involving humans that clearly supports the choice of all of the numbers in the Penalty Table. There is also no satisfactory biological model or mathematical formula relating radiation effects (of the type considered here) to exposure rates and durations that provides a satisfactory basis for deriving the amounts of exposure indicated in the table for time periods greater than one day. These are the best numbers available at the present time for this purpose.

Three examples of use of the Penalty Table are given here.

Example 1. It would be best if everyone's radiation exposure could be kept as low as possible, but due to wartime conditions, some individuals may have to spend some time in areas of higher radiation levels. Suppose you are trying to limit their radiation exposures to levels resulting in low medical risk. The numbers in Row A of Table 5 apply in this case. According to these numbers, it would be necessary to limit the total radiation exposure of individuals to less than 150 R in any one week (column a), 200 R in any one month (column b), and 300 R in any four-month period (column c).

For example, if individuals were exposed to the one-week limit of 150 R (column a) within the first week, then the limit for additional exposure during the following three weeks of the first month, to keep within the one-month limit (column b), would be  $200 \text{ R} - 150 \text{ R} = 50 \text{ R}$ . This additional exposure of 50 R could be received at any rate (for example, by going outside the shelter into areas of higher radioactivity) during the following three weeks of the first month, without exceeding the one-week or one-month limits in the Penalty Table. However, if this additional exposure of 50 R were received, for example, within the second week, then the individuals would have to be kept completely free of further exposure (which may not be possible) during the remainder of the first month to keep within the one-month limit for Row A (200 R). Similarly, if the individuals were exposed to the limit of 200 R in the first month, without exceeding 150 R in any one week of that month, the limit of additional exposure for the following three months of the first four months (column c) would be 100 R, for a total of 300 R ( $200 \text{ R} + 100 \text{ R}$ ) in four months.



Example 2. Suppose you need to conduct operations at the intermediate level of radiation exposure, involving significant medical risk (Row B), justified by highly critical emergency situations. The decision to conduct such operations must involve the Shelter Manager.

In this case, the decision-maker may find it necessary to allow greater exposure than one or another of the limits indicated in Row A but would be constrained whenever possible by other limits in Row A and always by limits in Row B of the Penalty Table.

For example, if individuals who have been exposed to 150 R within the first week are required in some emergency to be exposed to an additional 200 R during the remainder of the first month (for a total of 350 R in the first month), it is desirable, if possible, that the one-week constraint for Row A (column a) be observed by allowing no more than 150 R of this additional exposure during any one week within that month, even though the one-month limit (200 R) and four-month limit (300 R) for Row A will have been exceeded and the one-month limit (350 R) for Row B will have been reached. If it is not possible to keep within any of the constraints for Row A, then the Row B constraints have to be applied. In other words, you try to keep exposure in any one week as far as possible below 250 R and to limit the exposure during the first month to 350 R. Any additional exposure after this first month must be kept as far as possible below the additional 150 R which would attain the four-month limit of 500 R (Row B).

As in example 1, the decision-maker could schedule exposures in a variety of ways within the constraining limits to meet the work required by the problem at hand.

Example 3. Suppose you need to conduct operations at the high levels of medical risk (Row C), justified only by extremely critical emergency situations. Again the decision to conduct such operations must involve the Shelter Manager. Those activities that could result in saving a significant number of lives may call for the deliberate exposure of some persons at the highest constraint levels, where radiation sickness and a 50 percent probability of death are expected (Row C). If such situations arise, the decision-makers would use for guidance Row C of the table in a manner similar to that discussed for the low- and intermediate-risk rows (A and B) in examples 1 and 2 above.

After a time of no more than two weeks, it should be possible to move people from areas of high radiation levels to areas of lower radiation levels. In the areas of lower radiation levels, people should be able to get outside and work for different lengths of time as long as their radiation exposures stay within the limits of Row A of the Penalty Table. The "one-month" and "four-month" columns of the Penalty Table are intended primarily for these situations. No one should have to stay totally confined inside the shelters for more than two weeks, although people may have to live in them in some locations for longer periods.

#### 4.5.4 Checking Radiation Levels Beyond the Immediate Shelter Area

Sometime no later than 24-30 hours after fallout has begun to come down, you (the RM) should take the survey meter and check the radiation levels in rooms next to the shelter area and on the way to the outside. The purpose of this exploration is to get an idea how dangerous the levels are outside the immediate shelter area, to estimate the risks in emergency operations and to forecast when people could leave the shelter for short periods and when they could move to safer areas if needed.

Your experience and training make you very valuable to the occupants of the shelter. You should very carefully monitor your own exposure and make forecasts on your future exposures so you will not exceed the limits of exposure set in Row A of the Penalty Table (Table 5, p. 82).

If you used the time-averaging method to find the safest location in the shelter and the fallout pattern hasn't been shifted by wind or rain, you may use the results of those measurements to estimate the radiation levels in the other rooms which you checked, by using the ratio method. Suppose you stayed near location 1, your "home base", during the first 24 hours after fallout arrived. Now you want to find out how high the radiation level is at location 5. Suppose you included location 5 in your time-average comparison. Then you can estimate the present reading at location 5 by first finding the ratio of the time-average reading at location 5 to the time-average reading at location 1. Then multiply this ratio times the current reading at location 1 to get the current reading at location 5. In other words,

$$\text{Current reading at location \#5} = \frac{(\text{Time-average reading at location \#5})}{(\text{Time-average reading at location \#1})} \times \text{Current reading at location \#1}$$

The measurements at Erskine Hall will be used as an example. The time-average measurements for seven locations are listed in Table 4, p. 72, and survey-meter readings for location 1 are shown in Fig. 20, p. 64. Suppose we want to estimate what the survey-meter reading would be at location 5 at 2000 hr. From Fig. 20, the current reading at location 1, the reading at 2000 hr, is 6.0 R/hr. From Table 4 the time-average reading at location 5 is 0.81 R/hr and the time-average reading at location 1 is 0.315. The ratio of the time-average reading at location 5 to the time-average reading at location 1 is  $0.81/0.315 = 2.57$ . The reading at 2000 hr at location 5 is estimated to be  $2.57 \times 6 = 15.42$  R/hr.

Once the ratio of the time-average readings has been calculated, that same ratio can be used to estimate the reading at the remote location at any other time, assuming that the fallout pattern hasn't been shifted by rain or wind. For example, the estimated reading at location 5 in Erskine Hall at 2100 hr would be 2.57 times the reading at location 1 at that time, which is 5.5. The estimated reading at location 5 at 2100 hr would be  $2.57 \times 5.5 = 14.14$  R/hr.

You may use the ratio method to estimate the radiation levels, first, at various strategic locations inside your shelter building and, later, at various locations outside your building. First take a reading at your home-base location. Then take your survey meter (wear a dosimeter) to the strategic location and take a reading there. You will not need to use the time-average method after 24 hours after fallout has arrived because the radiation levels will be decreasing slower than 1% per minute. The ratio of the reading at the strategic location to the reading at the home base can be used to estimate readings at the strategic location by multiplying that ratio times the home-base readings.

As an example, the RM at Erskine Hall measured 2.1 R/hr at location 1, the home base, at 1000 hr on July 6. He took the survey meter up the stairs and made a quick trip into the lobby of Erskine Hall, where the survey-meter reading was 85 R/hr. The ratio of the lobby to home-base reading was 40. By 1000 hr on July 7, the home-base reading was 1 R/hr. The ratio of 40 was used to estimate that the radiation level in the lobby at that time was 40 R/hr.

At that time the RM took the survey meter upstairs and out to the street in front of Erskine Hall, where he measured a radiation level of 105 R/hr. His dosimeter showed an increase of 2 R for this trip, which he made as quickly as possible. The street to home-base ratio of readings was thus determined to be 105.

#### 4.5.5 Leaving the Shelter

When the exposure rates outside the shelter are known, Table 6 may be used as a general guide for permissible activities. Decisions on how much exposure may be allowed should be based strictly on the Penalty Table (Table 5, p. 82). Unit Leaders should continue to keep close track of the radiation exposure of each member until shelter is no longer required. If the shelter is vacated and people are moved to other shelters, it would be preferable if units remained together. Exposure records must go with the individuals to whom they belong.

If the fallout is relatively young (2 or 3 hours since fallout stopped coming down) and the radiation levels are decaying rapidly, greater relaxation of shelter control can be tolerated than indicated in Table 6. Conversely, if the fallout is relatively old (several days or weeks), more rigid control would be required.

Table 6. General guide for permissible activities

If the outside exposure rate (R/hr) has fallen to	Permissible activities
Less than 0.5	No special precautions are necessary for operational activities. Keep fallout from contaminating people. Sleep in the shelter. Always avoid unnecessary exposure to radiation
0.5 to 2	Outdoor activity (up to a few hours per day) is acceptable for essential purposes such as fire fighting, police action, rescue, repair, securing necessary food, water, medicine, and blankets, important communication, disposal of waste, exercise, and obtaining fresh air. Eat, sleep, and carry on all other activities in the best available shelter
2 to 10	Periods of less than an hour per day of outdoor activity are acceptable for the most essential purposes. Shelter occupants should rotate outdoor tasks to distribute exposures. Outdoor activities of children should be limited to no more than 10 to 15 minutes per day. Activities such as repair or exercise may take place in less than optimum shelter
10 to 100	Time outside of the shelter should be held to a few minutes and limited to those few activities that cannot be postponed. All people should remain in the best available shelter no matter how uncomfortable
More than 100	Outdoor activity may result in sickness or death. Occasions which might call for outside activity are (1) risk of death or serious injury in present shelter from fire, collapse, thirst, etc., and (2) present shelter is greatly inadequate--might result in fatalities--and better shelter is known to be only a few minutes away

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## GLOSSARY

The meanings of some of the specialized words and abbreviations used in this handbook are provided in this list, which is arranged alphabetically.

absorbed dose: the energy imparted to matter by ionizing radiation per unit mass of irradiated material at the point of interest. The unit of absorbed dose is the rad.

air burst: the explosion of a nuclear weapon at such a height that the fireball does not touch the earth's surface. Fallout from air bursts is negligible.

alpha particle: a positively charged nuclear particle identical with the nucleus of a helium atom that consists of two protons and two neutrons and is ejected at high speed from the nucleus of certain atoms in radioactive decay processes.

alpha radiation: rays of alpha particles.

alpha ray: an alpha particle moving at high speed, or a stream of such particles.

atom: the smallest particle of an element that still retains the characteristics of that element. Every atom consists of a positively charged central nucleus, which carries nearly all the mass of the atom, surrounded by a number of negatively charged electrons, so that the whole system is normally electrically neutral.

background radiation: nuclear radiations arising from within the body and from the surroundings to which individuals are always exposed. The main sources of the natural background radiation are potassium-40 in the body, potassium-40, thorium, uranium, and their decay products present in rocks and soil, and cosmic rays.

beta burn: damage to the skin caused by prolonged contact with particles which emit beta radiation.

beta particle: an electron (negatively charged particle) or a positron (positively charged particle) ejected at high speed from the nucleus of certain atoms in radioactive decay processes.

beta ray: a beta particle moving at high speed, or a stream of such particles.

beta radiation: rays of beta particles.

blast wave: a violent pulse of air in which the pressure increases sharply at the front, accompanied by winds, propagated from an explosion.

bone seeker: any compound or ion that migrates in the body preferentially into bone.

contamination: the deposit of radioactive materials on the surfaces of structures, areas, objects, or personnel.

CRP (crisis relocation planning): the planning for relocation of people from high-risk areas to areas of lower risk in the event of a crisis that brings the threat of nuclear war.

CSP (community shelter plan): the plan for people to use the best available shelters in their home communities in the event of a rapidly developing nuclear threat in which there is not time for crisis relocation.

cumulative dose: the total dose resulting from repeated exposure to radiation.

curie (abbr., Ci): unit of radioactivity equal to  $3.7 \times 10^{10}$  disintegrations per second.

decontamination: the removal or reduction of contaminating radioactive material from a structure, area, object, or person.

dose: a general term indicating the quantity of radiation or energy absorbed.

dose equivalent (abbr., DE): a quantity that expresses the detriment resulting from exposure to all kinds of radiation, defined as the product of the absorbed dose in rads and modifying factors; the unit of DE is the rem.

dose rate: absorbed dose delivered per unit time.

dosimeter: an instrument for measuring accumulated exposure to nuclear radiation.

dosimetry: the theory and application of the principles and techniques involved in the measurement and recording of radiation doses and dose rates. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made.

electron: an elementary particle having a negative electric charge of  $1.6 \times 10^{-19}$  coulomb and a rest mass 1/1836 that of the proton. In atoms, electrons surround the positively charged nucleus.

element: one of the known chemical substances that cannot be divided into simpler substances by chemical means.

emergency services: elements of government that are responsible for the protection of life and property, such as fire, police, welfare, and rescue services.

EOC (Emergency Operating Center): a well-protected headquarters at various levels of government, such as city, county, state, or region, with two-way radio and telephone communications with shelters, emergency services, other EOCs, and various government headquarters.

exposure: a quantitative measure of gamma or x-ray radiation at a certain place, based on its ability to produce ionization in air, measured in units of roentgens.

fallout: the process of the settling to the earth's surface of airborne particles containing radioactive material following a nuclear explosion; also refers to the particles themselves. Early fallout, also called local fallout, is that fallout which settles to the surface of the earth during the first 24 hours after a nuclear explosion. Delayed fallout, also called worldwide fallout, is that fallout which settles to the surface of the earth at some time later than the first 24 hours after a nuclear explosion. Most of the fallout from a surface burst will be deposited within 24 hours after a nuclear explosion and within 400 to 500 miles downwind from the explosion.

fallout half-value thickness: the thickness of a given material which will absorb half the gamma radiation incident upon it. This thickness depends on the nature of the material--it is roughly inversely proportional to its density--and also on the energy of the gamma rays. These factors are specially calculated for fallout radiation and include all processes of attenuation of radiation.

fallout protection factor (FPF): an indication of the degree of protection provided by a location against gamma radiation from fallout. The FPF for a location is defined as the ratio of the radiation exposure rate at 3 feet above a flat, smooth large open area to the radiation exposure rate at the location in question, when the same amount of fallout is deposited uniformly over both locations. If the FPF of a location is one, that location provides no protection against gamma radiation. This factor is also called the protection factor (PF). It is called "fallout protection factor" in this handbook because "protection factor" can mislead people into thinking that a location with a high "protection factor" will also protect against blast and thermal radiation.

fallout shelter: an enclosed area or place which can provide refuge and protection against fallout radiation by absorbing some or most of the radiation directed toward the shelter.



fireball: the luminous sphere of hot gases which forms a few millionths of a second after a nuclear explosion as the result of the absorption by the surrounding air of the radiation emitted by the extremely hot weapon residues. The exterior of the fireball is initially sharply defined by the luminous shock front and later by the hot gases themselves and may be visible for several minutes.

fission fraction: the fraction (or percentage) of the total yield of a nuclear weapon which is due to fission, the remaining fraction of the yield being due to fusion. For thermonuclear weapons the average value of the fission fraction is about 50 percent.

fission, nuclear: a nuclear transformation characterized by the splitting of a high-mass nucleus into at least two other nuclei of lower mass and the conversion of some of the initial mass into a relatively large amount of energy.

fission products: a general term for the complex mixture of substances produced as a result of nuclear fission. About 80 different fission fragments result from approximately 40 different modes of fission. The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains over 300 different isotopes of 36 elements.

FPF: see fallout protection factor.

fusion, nuclear: a nuclear transformation characterized by the uniting together of two or more low-mass nuclei into a nucleus of higher mass and the conversion of some of the initial mass into a relatively large amount of energy.

gamma radiation: rays of high-energy photons from radioactive material.

gamma ray: a photon of high energy, or a stream of such photons, emitted by the nuclei of certain atoms in radioactive decay processes.

gray (abbr., Gy): a proposed unit of absorbed dose of radiation equal to one J/kg or 100 rads.

ground burst: a nuclear detonation at the surface of the earth, or at such a height above the earth that the fireball makes contact with the surface.

ground zero: the point on the surface of the earth vertically below, at, or above the point at which a nuclear explosion is initiated.

group dosimetry: a method for estimating radiation exposures of individual members of a group when there aren't enough dosimeters for each member to have one.

half-life (radioactive half-life): the time in which half the atoms of a particular substance undergo radioactive decay.

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high-risk areas: geographical areas in the United States estimated to be subject to a 50% or greater probability of receiving blast overpressures of 2 psi or more in a nuclear war, or to a 50% or greater probability of receiving a radiation exposure of 10,000 R or more.

hot spot: a localized surface area of higher than average radioactivity.

initial nuclear radiation: nuclear radiation (essentially neutrons and gammas) emitted from the fireball and the cloud column during the first minute after a nuclear explosion. The time limit of one minute is set somewhat arbitrarily as that required for the source of the nuclear radiations to attain such a height that only insignificant amounts of radiation reach the earth's surface.

ion: an atom or molecule that has lost or gained one or more electrons to become electrically charged.

ionization: the process of adding electrons to or removing electrons from atoms or molecules.

isotopes: forms of the same element having identical chemical properties but differing in their atomic masses due to different numbers of neutrons in their respective nuclei and also differing in their nuclear properties, such as half-life, energy, and type of nuclear radiation emitted.

kiloton energy: approximately the amount of energy that would be released by the explosion of 1,000 tons of TNT, defined precisely as  $10^{12}$  calories, or  $4.19 \times 10^{19}$  ergs.

latency or latent period: the period of time between exposure to radiation and the detection of a specified effect of that exposure; or, for acute radiation sickness, the time during which no symptoms appear between the first reaction to radiation exposure and the later radiation sickness.

lethal radiation dose: the total-body radiation exposure required to cause death in 100 percent of a large group of people within a specified time period. For example, LD<sub>100/60</sub> indicates a dose which is lethal to 100 percent of the people exposed within 60 days after the exposure.

megaton energy: approximately the amount of energy that would be released by the explosion of one million tons of TNT, defined precisely as  $10^{15}$  calories, or  $4.19 \times 10^{22}$  ergs.

midlethal or median lethal radiation dose: the short-term total-body radiation exposure to cause death in 50 percent of a large group of people within a specified time period. For example, LD<sub>50/60</sub> indicates a dose which is lethal to 50 percent of the people exposed within 60 days after the exposure.

milliroentgen: 1/1000 of a roentgen. 1000 milliroentgens equals one roentgen.

neutron: an elementary particle having no electric charge and a rest mass of  $1.675 \times 10^{-27}$  kilogram. The neutron is a constituent of the nucleus of every atom heavier than ordinary hydrogen.

nuclear radiation: particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the weapons standpoint, are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true; X rays and nearly all ultraviolet radiation, for example, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atomic nuclei.

nuclear weapon: any weapon which attains its energy release from the fission or fusion of atomic nuclei.

nucleus: the positively charged central portion of an atom, composed of protons and neutrons and containing almost all of the mass of an atom but only a tiny part of its volume.

overpressure: the transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, in the shock (or blast) wave from an explosion. The variation of the overpressure with time depends on the yield of the explosion, the distance from the point of burst, and the medium, whether air, water, or soil, in which the weapon is detonated. The peak overpressure is the maximum value of the overpressure at a given location and is generally experienced at the instant the shock (or blast) wave reaches that location.

PF: see protection factor or fallout protection factor.

photon: a packet of electromagnetic energy having zero mass and no electric charge. Visible light is made up of low-energy photons, and gamma rays are high-energy photons.

protection factor (PF): this factor is called "fallout protection factor" in this handbook and is defined under that name. The term "protection factor" can mislead people into thinking that a shelter with a high protection factor will provide protection against blast.

proton: an elementary particle having a positive electric charge numerically equal to that of the electron and a mass of  $1.672 \times 10^{-27}$  kilogram. The proton constitutes the nucleus of the hydrogen atom and is a part of the nucleus of every atom.

RADEF: see radiological defense.

radioactive decay: a spontaneous nuclear transformation in which a nucleus emits alpha or beta particles, often accompanied by gamma radiation, resulting in a progressive decrease in the number of radioactive atoms in a substance.

radioactivity: the spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an unstable isotope. As a result of this emission the radioactive isotope is converted (or decays) into the isotope of a different daughter element, which may or may not also be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable, nonradioactive end product is formed.

radiological defense (RADEF): the organized effort, through detection, warning, and preventative and remedial measures, to minimize the effects of nuclear radiation from a nuclear attack on people and resources.

rem: a unit of dose equivalent, numerically equal to the dose in rads multiplied by factors such as the quality factor, which takes into account the higher concentration of damage by certain radiations such as heavy ionizing particles (alphas, neutrons, protons) along their paths through cells of the body.

remedial movement: transfer of people after a nuclear attack to provide better fallout protection, by moving people to a shelter with a higher FPF or to an area where the radiation levels are lower.

roentgen (R): A unit of radiation exposure determined by the amount of ionization produced in air. Specifically, it has been defined as the quantity of radiation that will ionize dry air at zero degrees centigrade and standard atmospheric pressure to produce one electrostatic unit of electric charge of each sign, both positive and negative, in one cubic centimeter.

shielding: any material or obstruction which absorbs or attenuates radiation and thus protects personnel or materials from the radiation effects of a nuclear explosion. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed to protect adequately from nuclear radiation.

sievert (abbr., Sv): a proposed unit of radiation dose equivalent equal to 100 rems.

skyshine: radiation, particularly gamma rays from a nuclear explosion or from fallout, reaching a target from many directions, mostly from above, as a result of scattering by air.

surface burst: same as ground burst.

survey meter: an instrument used to measure the exposure rate in roentgens per hour at the location being metered.

tenth-value thickness: the thickness of a given material which will decrease the intensity of gamma radiation to one-tenth of the amount incident upon it. Two tenth-value thicknesses will reduce the intensity received by a factor of  $10 \times 10$ , or 100, and so on. The tenth-value thickness of a given material depends on the gamma-ray energy, but for radiation of a particular energy it is roughly inversely proportional to the density of the material.

thermonuclear: an adjective referring to the process in which very high temperatures are used to bring about the fusion of light nuclei, such as those of the hydrogen isotopes deuterium and tritium, with the accompanying liberation of energy. A thermonuclear bomb is a weapon in which part of the explosion energy results from thermonuclear fusion reactions. The high temperatures required are obtained in this case by means of a fission explosion.

X ray: a photon of high energy, or a stream of such photons, resulting from processes other than nuclear transformations.

yield: the total effective energy released in a nuclear explosion. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion.

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## RADIATION EXPOSURE RECORD

Name \_\_\_\_\_

Home Address

Social Security No.

Shelter Address \_\_\_\_\_

Name of Shelter

Unit Leader

Rad. Sensitivity

Category \_\_\_\_\_

## RADIATION EXPOSURE RECORD

Name \_\_\_\_\_

Home Address

Social Security No. \_\_\_\_\_

Shelter Address

Name of Shelter

Unit Leader

Rad. Sensitivity

Category \_\_\_\_\_

[illegible][illegible]

[illegible][illegible]

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Name \_\_\_\_\_

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Social Security No. \_\_\_\_\_

Shelter Address \_\_\_\_\_

Name of Shelter

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Rad. Sensitivity

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[illegible]

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Unit Leader \_\_\_\_\_

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Category \_\_\_\_\_

[illegible]



[illegible][illegible]

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Name \_\_\_\_\_

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Social Security No. \_\_\_\_\_

Shelter Address \_\_\_\_\_

Name of Shelter

Unit Leader \_\_\_\_\_

### Rad. Sensitivity

Category \_\_\_\_\_

[illegible]

# RADIATION EXPOSURE RECORD

Name \_\_\_\_\_

Home Address \_\_\_\_\_

Social Security No. \_\_\_\_\_

Shelter Address \_\_\_\_\_

Name of Shelter

Unit Leader \_\_\_\_\_

Rad. Sensitivity

Category \_\_\_\_\_

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